SECT VI

OPTICAL TECHNOLOGY APOLLO EXTENSION SYSTEM PHASE A

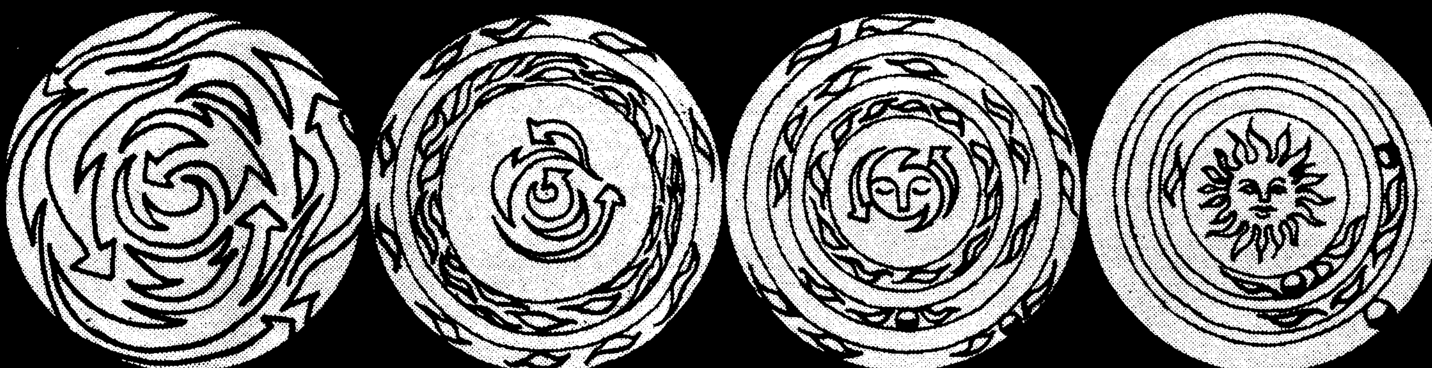
VOL VI

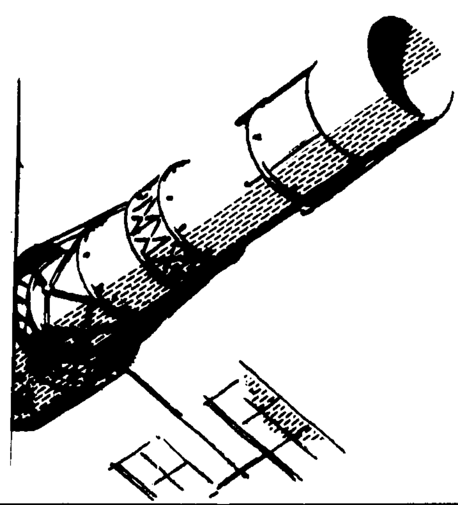
FINAL TECHNICAL REPORT

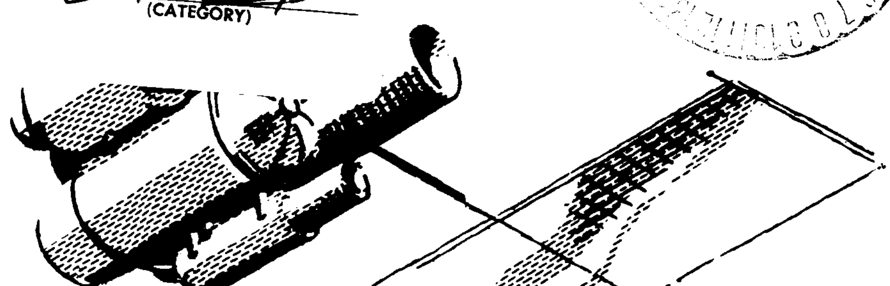
NAS 8-20256

RESOURCES ANALYSIS

SPACE DIVISION CHRYSLER CORPORATION







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OPTICAL TECHNOLOGY
APOLLO EXTENSION SYSTEM
PHASE A

FINAL TECHNICAL REPORT

VOLUME VI
SECTION VI

RESOURCES ANALYSIS

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PREFACE

The final report of the Optical Technology Apollo Extension System study prepared for NASA/Marshall Space Flight Center under Contract Number NAS8-20256 is presented in six volumes. The study was a team effort by Chrysler Corporation Space Division (CCSD) (prime contractor), Kollsman Instrument Corporation (KIC) and Sylvania Electronic Systems (SES).

Volume 1, containing the Program Results (1.0, 2.0, 3.0 and 4.0) and the Optical Technology Development Plan (5.0, 6.0, 7.0 and 8.0) was the responsibility of CCSD.

Volumes 2 and 3 contain the justified experiments (9.0 through 11.0), Integrated Experiment Requirements (12.0) and Other Experiments (13.0).

The SES experiments are:

- 9.6.1 Optical Heterodyne Detection on Earth
- 9.6.2 Optical Heterodyne Detection on the Spacecraft
- 9.6.3 Direct Detection Space to Ground
- 9.6.4 Communication with 10 Megahertz Bandwidth
- 9.6.8 10 Micron Phase and Amplitude Correlation
- 9.6.9 Pulse Distortion Measurements

The KIC experiments are:

- 9.6.5 Precision Tracking of a Ground Beacon
- 9.6.6 Point Ahead and Space-to-Ground-to-Space Loop Closure
- 9.6.7 Precision Tracking from One Ground Station to Another
- 10.2.1 Fine Guidance
- 11.4.1 Thin Mirror Nesting Principle
- 11.4.2 Primary Mirror Figure Test and Correction

The CCSD experiment is:

- 10.2.2 Comparison of Isolation Techniques

Volume 4 contains Systems Integration. CCSD prepared Candidate Missions (14.0), Manned Operation (15.0), Mission Analyses (16.0), Baseline Space Environment (17.0), Reliability (18.0) and System Requirements (20.0). SES prepared Ground Stations (19.0).

Volume 5 containing Subsystem Design was the responsibility of CCSD except for the Data Management Subsection which was prepared by SES. This volume includes Design Integration (21.0), Structural and Mechanical Subsystem Design (22.0), Guidance, Navigation and Control (23.0), Propulsion and Reaction Control (24.0), Electrical Power (25.0), Environmental Control (26.0), Thermal Control (27.0), Data Management (28.0), Weight and Mass Properties (29.0) and Crew Equipment (30.0).

Volume 6 containing the Resources Analysis (31.0, 32.0 and 33.0) was the responsibility of CCSD.

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VOLUME VI

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31.0 INTRODUCTION

The goals of the OTAES program are to provide the advances in technology and information for the development of both an interplanetary laser communication system, and a manned orbiting telescope. The purpose of this study is to establish the feasibility of an OTAES mission.

Resources analyses relate the various demands of the total OTAES system, and ensure the most efficient use of resources. To realize the full potential of the OTAES concept, the development program must optimize technical performance, cost, and schedule. The program plan contained in this document depicts a feasible solution of the attendant problems as they are presently defined. Figure 31.0-1 depicts the integrated OTAES team effort.

The program plan meets the following specific NASA Phase A requirements:

a. To identify the research and advanced technology requirements

b. To identify facility requirements

c. To develop gross plans for program implementation

These activities are integrated through the master phasing schedule, which represents the overall implementation of the program. Individual plans are:

a. Prerequisite Technology (PRT) Development Plan

b. Preliminary Design, Development, Test, and Evaluation Plan (DDT&E)

c. Preliminary Manufacturing Plan

d. Preliminary Test Plan

e. Preliminary Facilities Plan

f. Preliminary Cost Plan

g. Preliminary Schedule Plan

The Preliminary Manufacturing Plan is not a required study output, but is included for completeness.

31.0.1 Basic Ground Rules

a. The baseline spacecraft configuration, a modified Lunar Module, was arbitrarily selected to demonstrate concept feasibility.

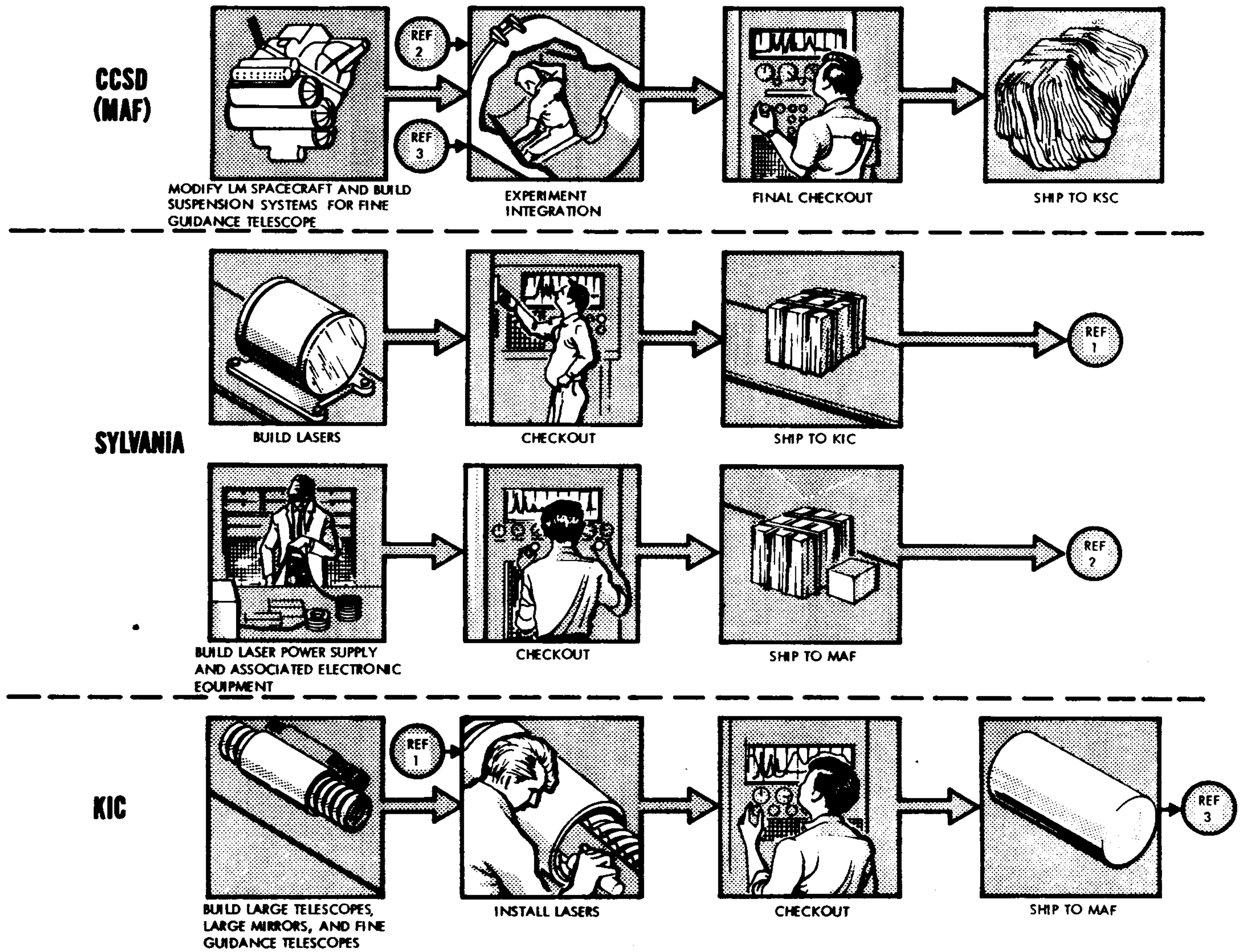

Figure 31.0.1. Flight Hardware Sequence of Operations

b. The essence of the OTAES program is experimentation which develops technology.

c. The cost for the 13 hardcore experiments, as a complementary package, is considerably less than the sum of the 13 individual experiment costs because of equipment commonality.

d. Costing and scheduling for the experiments will be by functional group (Laser 1-9, Large Optics 10 and 11, and Fine Guidance and Isolation Comparison 12 and 13) and not by individual experiment. (See c. above)

e. The costs are preliminary gross estimates based on studies and analyses conducted during Phase A.

f. Schedules are presented as the best estimates of the time necessary to accomplish tasks after the Authority to Proceed (ATP) for Phase B.

31.0.2 Program Definition

The OTAES baseline system reported in this study was evolved by use of best technical judgement in selecting one of the numerous approaches for performing the mission (see section 32.0 for detailed mission and program alternatives). Because this study is conceptual, certain assumptions were made which are applicable to the plans:

a. In Phase B, an evaluation of all spacecraft configurations and supporting subsystems will be made, as well as an expansion and refinement of the experiment base. The resulting output of Phase B will be an optimum spacecraft, and experiment configuration defined and recommended for the OTAES mission.

b. The Phase B study will provide refined resource costs schedules, and management plans based on the optimum concept. Preliminary specifications will be prepared.

c. Phase C, the final definition, will precede the hardware program.

d. Apollo system hardware will be used where practicable and economically feasible.

e. Launch vehicles and Apollo hardware will be available for use in the OTAES program.

31.0.3 Summary Planning Results

a. Figure 31.0.3-1 summarizes the OTAES program schedule from ATP-Phase B to launch of the OTES, a period of 54 months. The OTAES program schedule can be shortened by a period of 4 to possibly 10 months if adequate SR&T funding is provided promptly to

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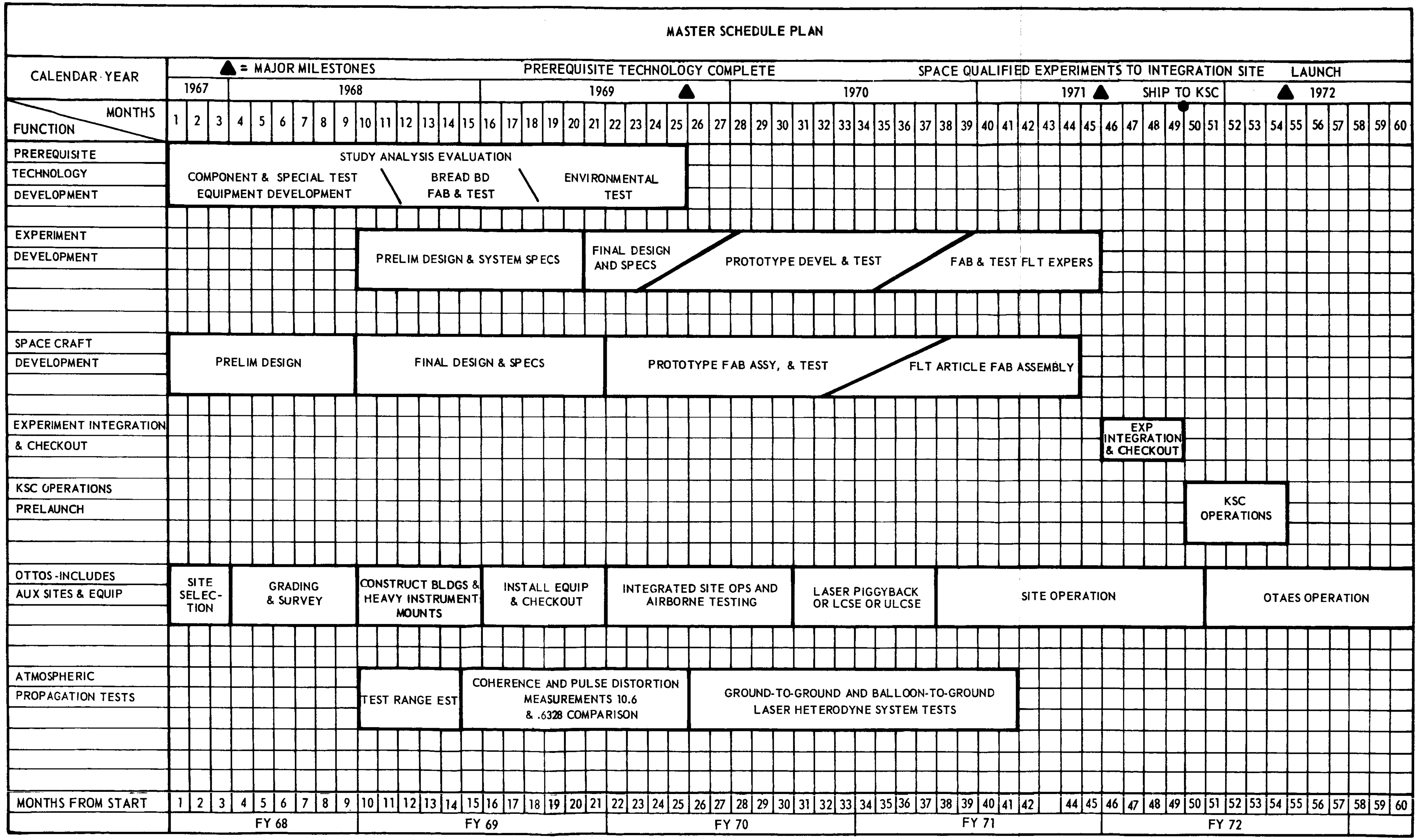

Figure 31.0.3-1. Master Schedule Plan

accomplish the prerequisite technology activities (research and technology advancement) delineated in the Prerequisite Technology Development Plan. The OTAES launch could then be scheduled as early as the third or fourth quarter of calendar year 1971.

b. Experiment developmental costs, including the costs for prerequisite technology are $21 million.

c. Spacecraft development costs are $137 million.

d. Non-recurring facilities costs are $24 million.

e. Launch vehicle and support spacecraft costs are $229 million.

f. Program management costs are estimated to be $12.3 million.

g. The total OTAES program cost is $423.3 million.

h. Detailed definition, costs, and schedules for the various program functions are provided in the individual plans.

31.0.4 Program Relationships

Implementation of the OTAES program will provide early, valuable information which will have a direct effect on ASTRA, MOT, and interplanetary missions including Venus or Mars flybys planned for the mid-1970's and later.

31.1 Prerequisite Technology (PRT) Development Plan

31.1.1 Introduction

The OTAES program has been defined as a logical and necessary step in achieving the goals of establishing an interplanetary communication system and a manned orbiting telescope. Advancements are required in several areas of technology and advanced methods or techniques must be developed and demonstrated before the presently defined 13 hardcore experiments of the OTAES program can be conducted in space.

31.1.2 Objectives

This prerequisite technology plan has been prepared to identify the technological advances required, and present an approach to provide that technology, through studies, design, and tests of breadboards representing the experiments. Preliminary gross costs and schedules are also presented; however, because prerequisite technology represents an advancement beyond the present state-of-the-art, the costs and schedules are only best estimates, based on studies and analyses conducted to date.

31.1.3 System Design

Systems Engineering will study the spacecraft mission requirements and the proposed system design with the purpose of maximizing total system performance. They will define and document technical interfaces among the spacecraft, telescope, laser, and suspension systems to ensure a completely workable system, and to avoid mismatches or gaps in the system at the point of integration and test.

System synthesis may lead to more than one system that will meet the mission requirements. The alternatives will be documented in such a way that the differences can be clearly recognized and compared. Trade-off studies will consider reliability, performance, and cost. Emphasis will be placed on keeping the spacecraft design moderate, and compensating at the ground station where possible.

The requirements of the system design will determine which prerequisite technology study areas receive the greatest emphasis. It may be possible to delete some anticipated studies while there may be a need to add others.

31.1.4 Reliability

The OTAES program requires the delivery of small numbers of each system. High reliability is as mandatory for the first system as for the second. Acceptance of relatively high risk in the first model, with reliability growth in later models, cannot be accepted. This makes it imperative that there be a thoroughly disciplined, systematic approach to reliability in the research and development effort. This degree of reliability can be achieved only by intense awareness and attention to detail by every member of the project team. A reliability training program will be initiated toward indoctrination of appropriate personnel in potential reliability problem areas.

Prediction models for the system will be developed. These models will be revised as required by evaluation of the system design, design change, and test results as they become available. These models will be used as:

a. A timely means of emphasizing potential reliability problem areas and guiding design trade-offs

b. A basis for reliability assessment in the reliability evaluation program

c. A guide for additional failure mode and criticality analysis to determine the effects on OTAES mission success

d. A basis for redundancy studies

31.1.5 Survey of Supporting Technology

Preliminary work has been done under NASA contracts that will directly support the OTAES program. Typical areas include laser frequency stabilization, space qualified laser, modulators, and propagation studies. A detailed survey of all related contracts will be made both for reference material and to prevent duplication of effort in the OTAES prerequisite technology effort.

31.1.6 Ground Rules and Assumptions

All schedules reflect the number of months to complete from ATP-Phase B. Funding will be available for PRT development. Delay or major modifications in funding will result in program slippage, and a probable increase in overall program costs. The point in time when all prerequisite technology is complete is identified as the Technology Readiness Date. On that date, all problems will have been identified, alternatives analyzed, solutions formulated, and advanced methods or techniques validated by demonstrations using breadboard equipment under comprehensive test conditions. Comprehensive test conditions include simulated launch and space environments.

There will be a continuation from the Technology Readiness Date to the design, test, and production of flight and ground station hardware. Therefore, emphasis will be placed on reliability, ruggedization, miniturization and producability of the hardware during the entire prerequisite technology. By including these disciplines from the beginning, several months of schedule will be saved at the start of the design/production phases.

31.1.7 Conclusions and General Summary

Assuming the Authority to Proceed-Phase B is October 1, 1967, all PRT activities will be completed by November 1969. The ground-to-ground and balloon-to-ground laser heterodyne system tests will be conducted concurrently with the design and hardware development phases, but will be completed in time for the results to impact on the flight hardware.

Funding required to accomplish the prerequisite technology activities is $6.4 million. Detailed information and charts are provided in the following sections.

31.1.8 Laser Group

The Prerequisite Technology Development of OTAES experiments 1 through 9 is presented in the following paragraphs.

31.1.8.1 Study Areas

The results of the laser mode control and stabilization study will be used to select suitable stabilization techniques for He-Ne and CO_2 lasers. Short- and long-term stability requirements and the affect of an orbital environment on stability will be considered.

31.1.8.1.1 He-Ne and CO_2 Laser Tubes

Numerous factors must be considered before the design of laser tubes for flight can be specified. These factors include:

a. Gas discharge factors (gas composition and pressure, current densities, bore diameter)

b. Optical resonator trade-offs

c. Discharge tube cooling requirements and techniques

d. Environmental effects

e. Optical materials for spacecraft operation

f. Remote optical alignment techniques

31.1.8.1.2 Gas Laser Ruggedization

The study results and analysis will be used to design rugged, environmentally resistent laser structures. Areas to be investigated are:

a. Environmental factors

b. Laser structure configuration

c. Acoustical isolation techniques

d. Structural materials

31.1.8.1.3 Video Modulators

Audio, frequency, and phase modulation techniques will be studied to determine which is the most desirable for space communications. One particular problem is that suitable materials for 10.6-micron optical modulators is limited.

31.1.8.1.4 Frequency Translation

Program goals are to investigate laser frequency translation techniques, (optical parametric oscillation, Zeeman and Stark splitting, electro-optic modulators, etc.) in order to develop tunable laser oscillators. Future interplanatery missions will involve large Doppler frequency shifts, and require tunable local oscillators for optical, heterodyne, communications systems. This program will have large impact on ground station design if it is successful, because heterodyne receivers can then be used even with large Doppler shifts on the incoming signal.

31.1.8.1.5 Photodetectors

State-of-the-art advancement is needed in visible and infrared photodectectors. At 0.6328 micron, high quantum efficiency, wideband photomultiplier tubes need development. For 10.6-micron detection, bulk photoconductors are photodiodes with high quantum efficiency, increased responsivity, and decreased cooling requirements need development.

The heterodyne receiver optical system study will define the optical system trade-offs, 0.6-micron optical system requirements, 10.6-micron optical system requirements, dichronic mirror requirements, and the optical interference filter.

31.1.8.1.6 Ground Station Mechanical Configuration

Preliminary definition and design of the optical-mechanical subsystem will be performed. Evaluation will be made for providing either a single, large-aperture 10.6-micron telescope, or adjustable multiple apertures to measure 10.6-micron phase coherence diameter. Phase coherence measurements at 10.6-microns will be necessary to optimize ground receiver design.

Ground-to-ground atmospheric propagation studies will be required before the flight of OTAES, to enable prediction and interpretation of results from satellite laser communications.

31.1.8.1.7 Large-Aperture Receiver

Analysis of optical parameters will be made. The design of filters, mirrors, secondary optics, and electronic controls will be made for a 3-meter diameter prototype receiver. Development work on lightweight mirrors and large area filters will follow the design effort. The prototype will be manufactured, assembled, and tested. Measurements will be made to determine accuracy, resolution, and angle of acceptance of the receiver.

31.1.8.1.8 Laser Interfaces

Techniques will include those for changing the power distribution in the beam group section, and definition and design of achromatic collimating optics to optimize wavelength range. Overall definition and design compatibility of lasers and telescopes will be prime considerations.

31.1.8.1.9 Precision Tracking

Definition and comparison of acquisition techniques, and atmospheric effects on laser beams will comprise the major portions of this study. Identification and analysis of planet tracker accuracy and definition of systems for minimizing nonlinearity of deflectors by means of beam angling and translation will also be undertaken. Servo systems are required for stability and frequency response.

31.1.8.1.10 Point Ahead and Space-to-Ground-to-Space Loop Closure

The relationship of the number, size, and distribution of the ground array of telescopes to pointing accuracy will be investigated. Definition and design of pointing correction techniques will be accomplished.

31.1.8.1.11 Ground Station Requirements

The requirements for sequencing and synchronizing tracking functions between separate ground stations and the spacecraft will be defined. Ground array interface definition, and the number and location of ground tracking sites needed will be presented.

31.1.8.2 Breadboarding and Test

31.1.8.2.1 Validation of Methods or Techniques

The next step after study and preliminary design is the validation of methods or techniques by breadboarding and testing. Three units have been chosen for validation:

a. He-Ne Laser Transmitter

b. CO_2 Laser Transmitter

c. He-Ne/CO_2 Combination Receiver

Systems Engineering and Reliability will correlate the study date and provide inputs to the detailed design for the breadboard units. Initial units will receive functional test and then will be installed in the breadboard system. Additional components will undergo environmental tests to ensure that they will pass space qualification requirements in the areas of temperature, vacuum, vibration, RFI, and life. Some critical areas of the design will include laser tubes and remote tuning.

a. Laser Tubes. The most critical factor in producing a space-qualified laser will be in the laser tube itself. The tube must be constructed to withstand high vibration requirements and must be provided with suitable mechanical mountings. Heat dissipation and outgassing remain major problems to be solved. Operating life will require a state-of-the-art advancement.

b. Remote Tuning. Reliable methods must be developed to compensate for drift of the laser frequency caused by vibration, temperature, and age.

The laser breadboards will be subjected to tests similar to those required for space qualifications. Test results will be fed back to Reliability and the design engineers, and modifications will be incorporated as needed. Successfully completing these tests will be the final requirement in demonstrating the validity of methods or techniques.

31.1.8.3 Special Test Equipment

A three-rack test console will be developed for use during compatibility, functional, environmental, and life tests on operating laser systems. Similar consoles will be used for tests at the telescope and spacecraft contractor facilities.

The test console will provide control, signals, power, regulation, monitoring, and recording. The first console will be required 11 months after the ATP for Phase B.

31.1.8.4 Facilities

An additional 1,600 square feet of laboratory space will be required by the optical systems department for design, development, test, and integration of laser systems. This facility will be required 11 months after the start of Phase B.

31.1.8.5 Atmospheric Propagation Studies

31.1.8.5.1

Although these studies may influence equipment design, their primary purpose is to produce knowledge. The studies will be required before the flight of OTAES to make possible prediction and interpretation of results from satellite laser communications.

The program will be conducted in three phases prior to OTAES launch. Phase 1 includes studies and plans. Phase 2 consists of equipment design and fabrication, facilities development, and preliminary measurements. Ground-to-ground measurements and balloon-to-ground measurements make up the third phase.

31.1.8.2 First Phase

Studies of work done under previous contracts will be conducted to determine how much of the work is applicable to the atmospheric propagation studies. Additional work will be specified to meet the OTAES requirements. Equipment will be specified for the next phases and a detailed plan drawn to conduct the atmospheric measurement tests.

31.1.8.3 Second Phase

Portable laser transmitters and receivers will be developed or procured to permit measurements to be made over variable atmospheric paths.

Sylvania maintains two facilities that will be suitable for ground-to-ground tests.

A 100-yard test range is maintained at the Mountain View Laboratory for short range tests and controlled tests using beam-folding with mirrors.

A two-station antenna test range is maintained in the Santa Cruz Mountains. The two stations are located on mountain ridges 7,000 feet apart. A 20-mile direct transmission path is available between one station and the Mountain View Laboratory.

Preliminary measurement goals are to measure atmospheric propagation of 0.6328-micron and 10.6-micron laser radiation over short ground-to-ground path lengths (paths greater than 1 kilometer). Laser propagation measurements will include:

a. Pulse distortion at 0.6328 microns (a mode-locked He-Ne laser will generate subnanosecond optical pulses).

b. Effective receiver coherence diameter at 10.6 microns.

c. Dependence of laser propagation on atmospheric variables.

d. Simultaneous test at 0.6328 and 10.6-microns to determine wavelength dependence.

Experimental results will be correlated with atmospheric turbulence theory and models where appropriate.

31.1.8.5.4 Third Phase

The ground-to-ground measurements phase will be a continuation of the second phase measurements, but a more sophisticated heterodyne receiving system will be used.

Program goals are to evaluate video bandwidth optical communication systems operating at 0.6328 and 10.6-microns over ground-to-ground atmospheric paths. Laser propagation measurements will include:

a. Amplitude fluctuations of heterodyne signals.

b. Frequency (or phase) fluctuations in heterodyne signals.

c. Polarization fluctuations in heterodyne signals.

d. Fading and fading rate of various modulated signals.

Laser heterodyne systems used in this program are based on OTAES-developed components. The atmospheric testing program is also a test of component performance and reliability.

Experiment results will be correlated with atmospheric turbulence theory and models where appropriate.

Portable laser transmitters and receivers will be developed so measurements can be made over variable atmospheric paths. Final atmospheric propagation measurements will be integrated with OTAES ground heterodyne receiver development to check receiver performance.

Since weather variations during the year make it desirable to have site flexibility, no fixed site for balloon-to-ground tests is proposed. SES/ARL has developed a mobile laser-tracking facility that will satisfy the requirements of this experiment. The balloon and launching equipment will be provided by a Subcontractor.

Balloon-to-ground testing goals are to measure atmospheric propagation of 0.6328- and 10.6-micron laser radiation over a high altitude balloon-ground receiver path length. Laser propagation measurements will be based on previous ground-to-ground test program results. Many of the parameters measured in previous testing will be measured over high altitude paths for comparison and verification of theory or models. Laser propagation measurements will include:

a. Amplitude and frequency (or phase) fluctuations in heterodyne signals.

b. Polarization fluctuations as indicated from previous programs.

c. Pulse distortion as indicated from previous programs.

d. Fading and fading rate of selected modulation techniques.

Experimental results will be correlated with atmospheric turbulence theory and models where appropriate.

The balloon test will use OTAES-developed components where possible to provide performance and reliability data. The test will be integrated with OTAES ground receiver development where possible to check receiver performance.

<u>31.1.8.5 Schedules</u>

Figure 31.1.8.5-1, an overall logic flow diagram for the Laser Groups, shows the major study areas and their associated analyses, interrelationships, breadboard development, and environmental testing.

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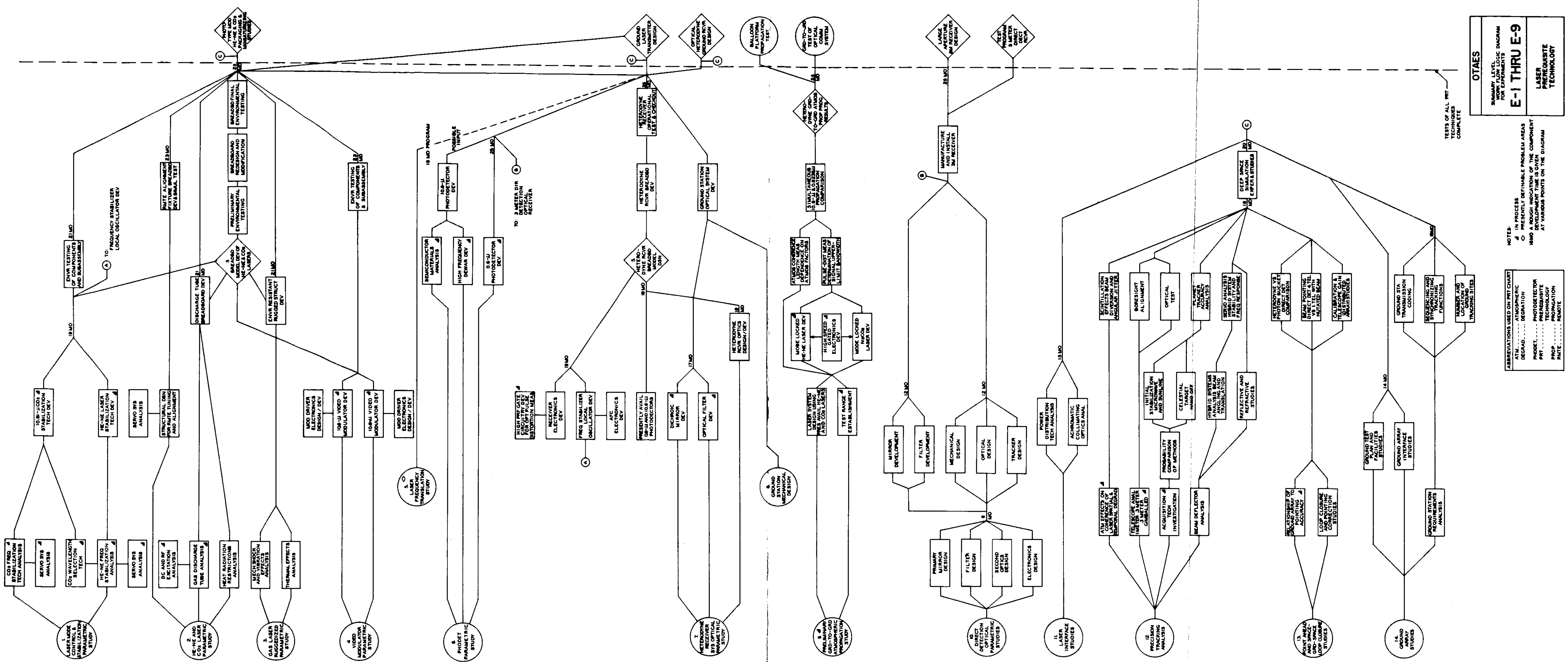

FIGURE 31.1.8.5-1 PRT LASER GROUP LOGIC FLOW DIAGRAM

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The technology readiness date is 25 months after the ATP for Phase B.

31.1.8.6 Costs

The costs for prerequisite technology are shown in table 31.1.8.6-1 and relate to the major study areas and tasks shown in figure 31.1.8.5-1.

Prerequisite technology costs will be \$3.3 million and atmospheric propagation test costs will be \$1.04 million, a total of \$4.5 million.

31.1.9 Large Optics Group

The Large Optics Group consists of experiments 10 and 11, Primary Mirror Figure Test and Correction, and Thin Mirror Nesting Verification.

31.1.9.1 Study Areas

31.1.9.1.1 Primary Mirrors

Thermal studies and tests will define the need for mirror temperature control and optimum thermal sensing and control configuration. Effects of launch and orbit environments will be determined and correlated with mirror support requirements, figure control methods, and fabrication methods and materials.

31.1.9.1.2 Temperature Actuator and Controls

Actuator temperature sensor requirements will be defined and materials selected. Thermal insulation requirements will be determined. The thermal control servoloop system will be defined and designed.

31.1.9.1.3 Scatter Plate Interferometer

Detailed task definitions for analysis, study, and research activities will be prepared and preliminary breadboard system fabrication and test tasks will be defined. An algorithm for system input/output relationship as a function of system parameters will be derived. The effect of contrast and intensity variations on resolution of mirror figure deviation will be determined and a means of improving the scattering angle will be determined and defined. Optical alignment and positioning tolerances will be calculated and limits on allowable error will be set. Alternative interferogram imaging and recording requirements will be compared. Light source and power requirements and bandwidth stability will be determined. Detailed design and specifications for breadboards and breadboard testing will be prepared.

31.1.9.1.4 Pneumatic Suspension Systems

Thin mirror suspension systems requirements will be defined and pneumatic/alternate protection systems for the launch environment will be analyzed and compared.

TABLE 31.1.8.6-1
PRT COSTS LASER GROUP

No.	Title	Cost $K
1	Laser Mode Control & Stabilization	$292
2	He-Ne and CO_2 Lasers	248
3	Gas Laser Ruggedization	312
4	Video Modulators/Optics	219
5	Laser Frequency Translation	146
6	Photodetectors	204
7	Heterodyne Receivers/Optics	388
8	Ground Station	73
9	Atmospheric Propagation	270
10	Direct Detection Optics	650
11	Laser Interface Studies	12
12	Precision Tracking	159
13	Point Ahead and Space-to-Ground-to-Space Loop	51
14	Ground Array	30
	Optical Interferometer (Experiment 8)	300
	3 Meter Direct Detection Receiver Tests	200
	Ground-to-Ground and Balloon-to-Ground Laser System Tests	834
		$4,388

Manpower $3,325 thousand
Material $1,063 thousand

Special Test Equipment	$ 75	thousand
Facilities	50	
Grand Total	$4,513	thousand

Nos. refer to major areas shown in Figure 31.1.8.5-1 PRT logic flow diagram.

31.1.9.1.5 Secondary Mirror

Thermal requirements will be determined, material will be selected, and the need for optical alignment devices will be defined.

31.1.9.2 Breadboarding and Test

31.1.9.2.1 The units chosen for breadboarding and test are:

a. 20-inch and 50-inch model thin mirrors.

b. 20-inch and 50-inch model active controlled mirrors with model actuator system.

c. Scatter plate interferometer.

Two thin mirror models 20-inch and 50-inch diameter, will be fabricated to test fabrication methods and to allow detailed testing, resulting in figure checks and development of scaling laws. Nests will be designed and fabricated for each model. Thermal tests will be conducted to determine if thermal controls are necessary. Optimum thermal control configuration will be determined. A model suspension system will be designed and fabricated, and static and dynamic tests will be conducted to validate prediction techniques.

Prepare designs, fabricate and test two model mirrors, 20-inch and 50-inch diameter to accommodate mechanical actuators bearing on back survey. A single unit mechanical actuator will be fabricated and tested to evaluate control and response sensitivity. Then a complete set of mechanical actuators will be fabricated and figure correction tests of a flat circular plate will be performed to validate study results. Integrated tests of mirror models, mechanical actuator arrays, reference frames, thermal controls, and optical instrumentation will be performed to check radii of curvature and surface pertubations of the model mirrors, using a Foucault tester and the scatter plate interferometer. The actuator array will be used to attempt figure correction.

Thermal tests will be conducted and an optimum thermal control configuration designed.

A breadboard of the scatter plate interferometer and the breadboard system will be designed and fabricated. The breadboard system will be aligned and checked out with a Standard Test Mirror and with the experimental thin or active figure controlled model mirrors. The scatter plate interferometer will be used to test the experimental mirrors to derive figure data. Test and analytical results will be compared and a report prepared giving conclusions and recommendations for the scatter plate interferometer design.

31.1.9.3 Schedules

Figure 31.1.9.3-1 depicts the studies, development activities, and testing for the Large Optics Group.

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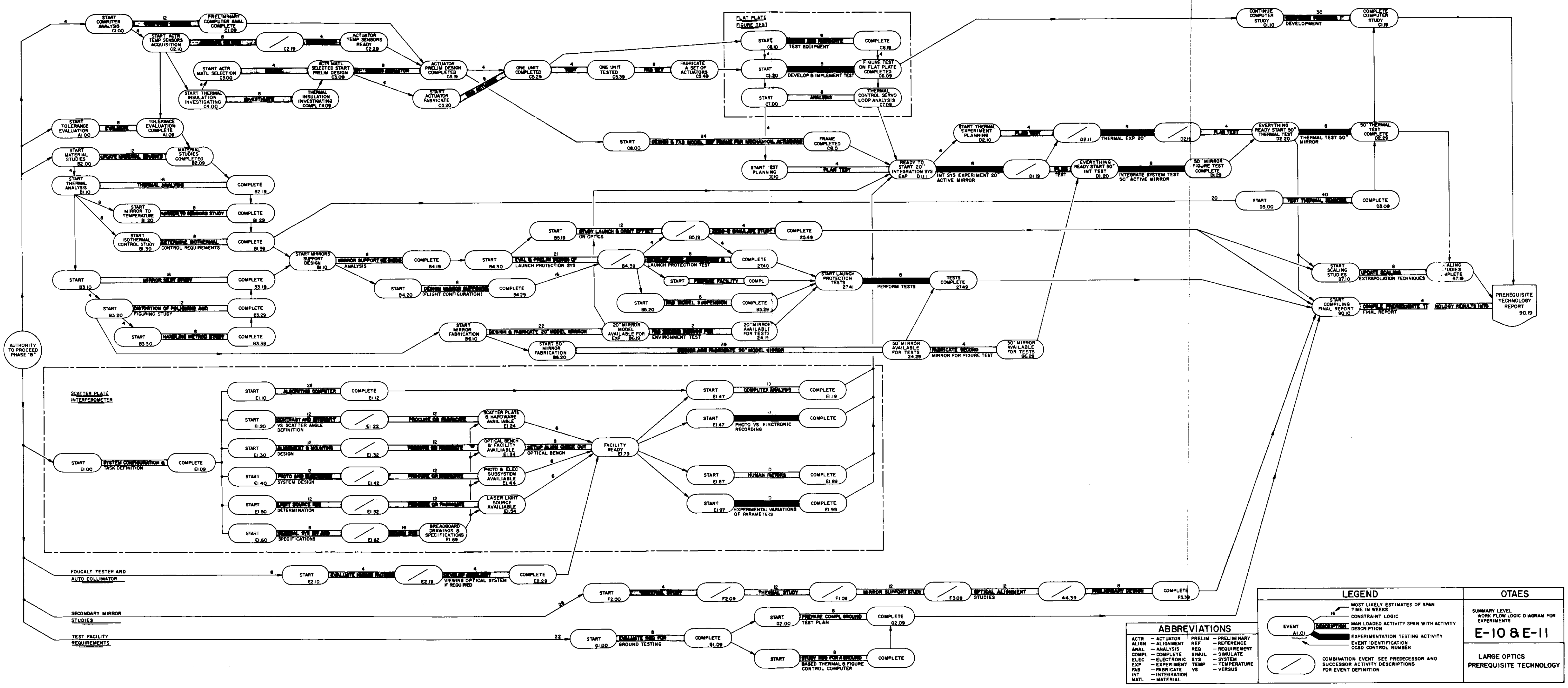

FIGURE 31.1.9.3-1 PRT LARGE OPTICS GROUP LOGIC FLOW DIAGRAM

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The technology readiness date is 20 months after ATP for Phase B.

31.1.9.4 Costs

The detailed costs for prerequisite technology are shown in table 31.1.9.4-1. The total cost for Large Optics Group prerequisite technology activity is $0.88 million.

31.1.10 Fine Guidance and Isolation Comparison Group

Prerequisite technology activities for experiments 12 and 13, Fine Guidance and Comparison of Isolation Techniques, are presented in this subsection.

31.1.10.1 Study Areas

31.1.10.1.1 Systems Concept

The results of the systems concept study will be used to determine tracking methods (direct versus offset) as a function of star magnitude and the relationship of tracking capability to background noise, star magnitude, and color temperature.

31.1.10.1.2 Fine Guidance Telescope

System configuration and alignment techniques will be determined. Scanning methods will be compared and a suitable method selected. An analysis of maximum resolution will be made.

31.1.10.1.3 Fine Sensors

The results of this study will be used to determine which types of sensors require further development and which types are best suited for use in the flight experiments. Several of the fine sensors will be selected for testing.

31.1.10.1.4 Actuation System

An analysis will be made of the various fine beam deflectors, actuators, and control systems to provide a system which will meet mission system requirements. Test plans for the various selected systems will be prepared.

31.1.10.1.5 Light Detectors

The results of this study will be used to determine whether solid state photocathodes, light amplifiers, or imaging devices offer the optimum approach for system requirements.

31.1.10.1.6 Suspension Systems

Suspension system requirements will be defined and test models of the various configurations will be designed. Data transmission techniques will be developed for each of the configurations and damping techniques and caging methods

Table 31.1.9.4-1
PRT Costs-Large Optics Group

Activity		Cost (in thousands of dollars)
A.	Activities common to experiments 10 and 11	
	Experimental concept studies	$ 4.5
	Thermal, material, and fabrication method studies	36.0
	Optical instrumentation development scatterplate Interferometer, Foucault tester, and autocollimator	144.0
	Secondary mirror studies and preliminary design	36.0
	Test facility requirements study	12.0
	Scaling studies	4.0
B.	Experiment 10-Primary Figure Test and Correction	
	Mirror support methods study (launch and orbit), preliminary design of launch protection system	27.0
	Effects of launch and orbital environment on figure and optical quality	13.0
	Design, and fabrication of model mirrors	216.0
	Mechanical actuators and controls, design, fabrication and test	85.0
	Integrated test of mirror models using reference frame, actuators thermal controls, and optical instrumentation	44.0
C.	Experiment 11 - Thin Mirror Nesting Design and Fabrication of Model Mirrors and Nests	174.0
	Figure and thermal tests of model mirrors, and test of thermal sensors	43.0
	Mirror support method studies (orbit configuration)	10.0
	Mirror protection system studies (launch)	12.0
	Design, fabrication and test of model launch suspension system	18.0
	Total	$ 878.5

Manpower $560.5 thousand
Material $318 thousand

will be defined. Test plans will be prepared for use in evaluating and comparing the alternate systems and components.

31.1.10.2 Breadboarding and Test

31.1.10.2.1 In conjunction with the studies and analyses several components and systems will be tested to confirm the study findings and compare the alternatives. Testing will be conducted on the actuator systems, actuators, fine sensors, and light detectors and on telescope suspension and control systems.

After testing, results will be compared and analyzed. Mission systems requirements will be used to prepare the specifications and designs for recommended flight systems.

31.1.10.3 Facilities

To perform the research and development work on the suspension systems proposed for the isolation experiment, requires a facility in which the low-g dynamics of the orbital environment can be simulated. The simulation facility should support the weight of the telescope but provide for a dynamic response similar to that which would occur in space. Also, provision should be made for simulating the telescope and its control and stabilization systems. This facility has been designed and is described briefly as follows:

A simulated telescope, including a fine pointing system, is mounted on a plot airbearing table to provide a low friction support in two axes of translation and one of rotation. To simulate orbital g forces, the table is kept level with a two-axis control system to a sub-arc-second stability, and the tilt may be varied on command within this range to simulate a mission time period. Mounted around this table is a simulated spacecraft structure, which can be driven with an external exciter to simulate the disturbance to a manned spacecraft in orbit. The suspension systems to be tested are mounted between the simulated spacecraft structure and the telescope. Then, while the suspension systems are driven by the spacecraft structure, the simulated telescope fine pointing system tracks a simulated star source attached rigidly to the airbearing table.

31.1.10.4 Schedules

Logic flow diagrams for experiments 12 and 13 are shown in figures 31.1.10.4-1 and 31.1.10.4-2, respectively. The figures show studies, breadboard development, testing, and activity interrelationships.

The technology readiness date is 20 months after the ATP for Phase B.

31.1.10.5 Costs

The costs for major prerequisite technology activities are shown in table 31.1.10.5-1. The total cost for Fine Guidance and Isolation Comparison Group prerequisite technology is $0.98 million.

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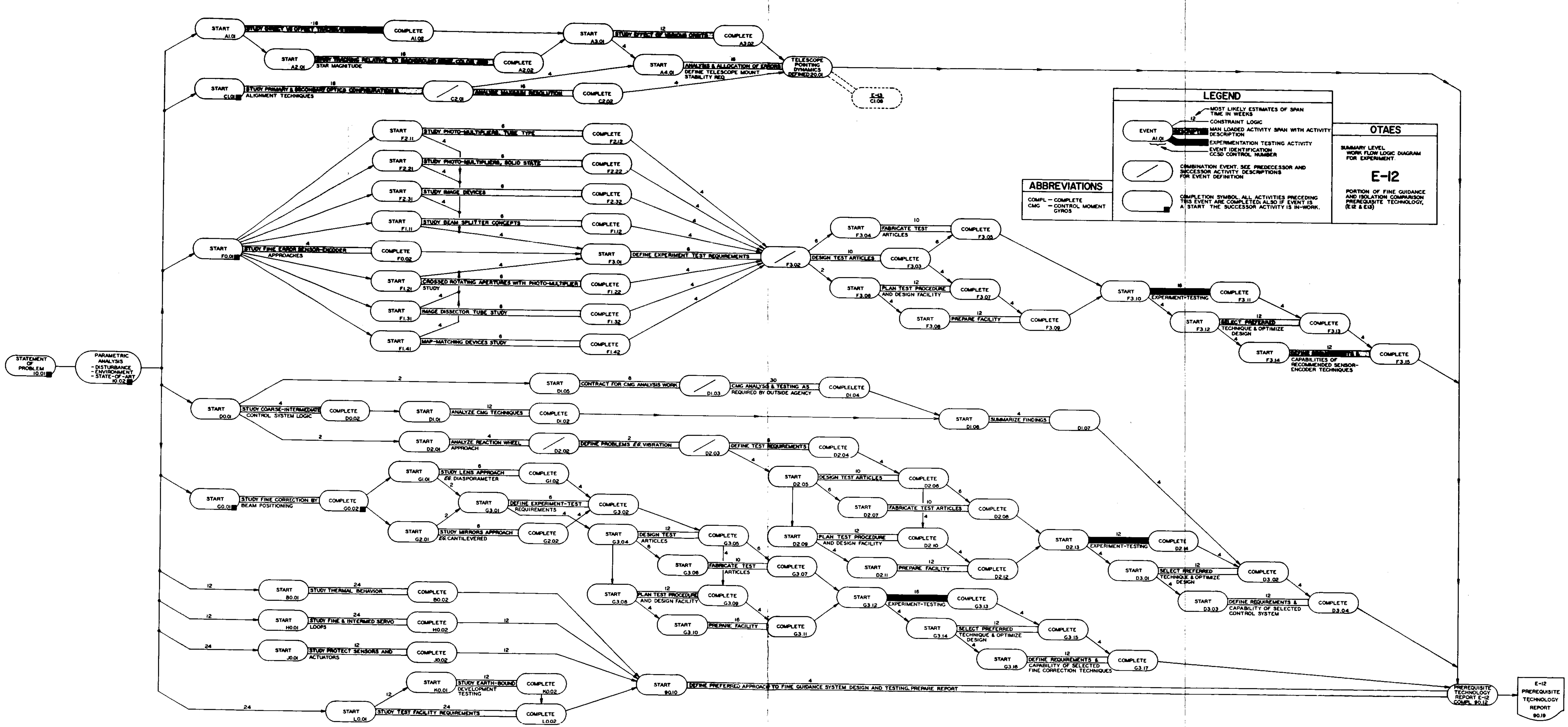

Figure 31.1.10.4-1. PRT Fine Guidance--E-12

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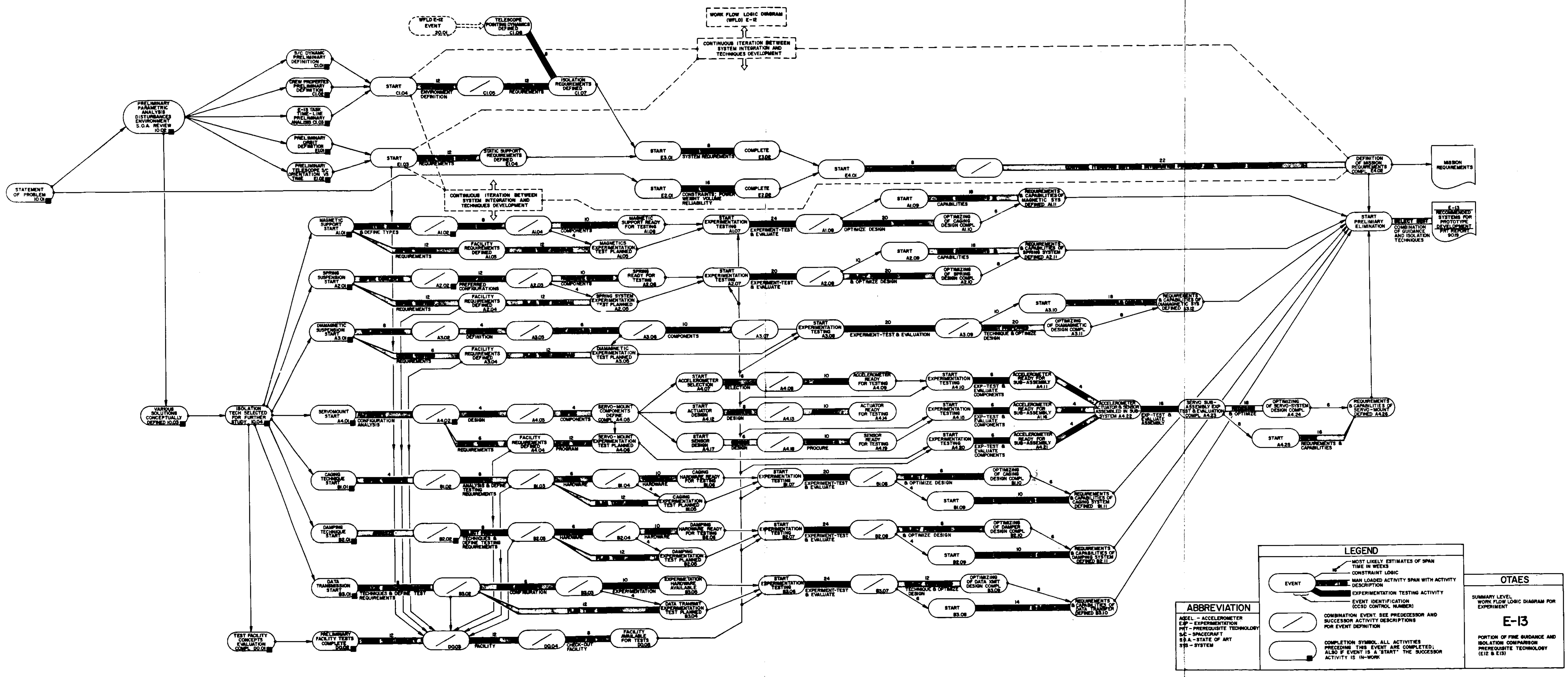

FIGURE 31.1.10.4-2 PRT COMPARISON OF ISOLATION TECHNIQUES-E-13

Table 31.1.10.5-1
PRT Costs Fine Guidance and Isolation Comparison Group

Activity	Cost (in thousands of dollars)
Experiment 12 - Fine guidance	
Systems concept studies, direct versus offset tracking and tracking capability	$ 54.0
Thermal studies	18.0
Telescope studies, primary and secondary optics, system configuration and alignment	24.0
Fine sensor studies, development and test (pyramidal deflector, image dissector tube, etc.)	133.0
Actuator system studies, fine beam deflector studies and tests	56.0
Light detector analysis and test	23.0
Servo loop studies	9.0
Protect sensor and actuator studies	6.0
Development test and test facility studies	9.0
Experiment 13 - Comparison of Isolation Techniques	
Magnetic support system analysis design, fabrication test and evaluation	88.8
Spring-mount analysis, design, fabrication, test and evaluation	43.4
Diamagnetic suspension system analysis, design, fabrication test and evaluation	101.6
Servo mount system analysis, design, fabrication, test and evaluation	251.0
Caging mechanism analysis design, fabrication, test and evaluation	28.6
Damping technique analysis, design fabrication, test and evaluation	29.0
Data transmission techniques analysis, design, fabrication, test and evaluation	36.0
Isolation requirements analysis and definition of mission constraints	37.0
	$947.4

Manpower $774.4 thousand
Material $173.0 thousand

Facilities	$ 40.0
Grand Total	987.4

31.2 EXPERIMENT RELATED PLANS

31.2.1 Preliminary Design, Development, Test, and Evaluation Plans

31.2.1.1 Introduction

The experimental program will provide maximum technological and scientific information. This information can best be learned from an orbital environment. The program consists of 13 hardcore experiments, which will be integrated within a modified Lunar Module, with the complete descent stage and the ascent stage propulsion system removed. The 13 experiments, which are typical of the type of experiments that will be selected for flight, are:

1. Optical Heterodyne Detection on Earth
2. Optical Heterodyne Detection on the Spacecraft
3. Communication with 10 Megahertz Bandwidth
4. Direct Detection Space to Ground
5. Precision Tracking of a Ground Beacon
6. Point Ahead and Space to Ground to Space Loop Closure
7. Transfer Tracking from one Ground Station to Another
8. Phase Correlation Measurement
9. Pulse Distortion Measurement
10. Primary Mirror Figure Test and Correction
11. Thin Mirror Figure Test and Correction
12. Fine Guidance
13. Comparison of Isolation Techniques

The hardcore OTAES experiments have been further grouped into three major categories (figure 31.2.1.1-1):

a. Laser Group (experiments 1 through 9)

b. Large Optics Group (experiments 10 and 11)

c. Fine Guidance and Isolation Comparison Group (experiments 12 and 13)

HARDCORE OTAES EXPERIMENTS	MAJOR CATEGORIES	END RESULTS
1. OPTICAL HETERODYNE DETECTION ON EARTH 2. OPTICAL HETERODYNE DETECTION ON THE SPACECRAFT 3. COMMUNICATION WITH NO MEGAHERTZ BANDWIDTH 4. DIRECT DETECTION SPACE TO GROUND 5. PRECISION TRACKING OF A GROUND BEACON 6. POINT AHEAD AND SPACE-TO-GROUND-TO-SPACE LOOP CLOSURE 7. TRANSFER TRACKING FROM ONE GROUND STATION TO ANOTHER 8. PHASE CORRELATION MEASUREMENT 9. PULSE DISTORTION MEASUREMENT	LASER GROUP	OPTIMUM SPACE OPTICAL TECHNOLOGY EXPERIMENTS
10. PRIMARY MIRROR FIGURE TEST AND CORRECTION 11. THIN MIRROR NESTING PRINCIPLE	LARGE OPTICS GROUP	
12. FINE GUIDANCE 13. COMPARISON OF ISOLATION TECHNIQUES	FINE GUIDANCE AND ISOLATION COMPARISON GROUP	
. . . n. NEWLY DEVELOPED EXPERIMENTS	ADDITIONAL EXPERIMENT GROUPS	

Figure 31.2.1.1-1. Grouping of Experiments

Experiment hardware commonalities, similarities of technical measurements and data to be obtained, and economics factors make these categories optimum.

Even though newly justified experiments may be added to the basic hardcore experiments, the three categories are representative of the type of experiments which will be conducted. For each of these categories, the Preliminary Design, Development, Test, and Evaluation Plan may be broken down into the following basic activities:

a. Preliminary hardware design

b. Preliminary layouts

c. Development Testing

d. Analysis and final specifications

e. Detailed design

f. Qualification

The experiment hardware must be designed for maximum reliability and safety, ease of manufacture, and the durability to perform properly throughout the entire mission. During the design and development of the experiment hardware, design reviews will be conducted to ensure that all objectives and design criteria are adhered to.

Once the detailed design has been thoroughly evaluated and all recommended design improvements incorporated into the hardware, the necessary detailed and production drawings and other documentation will be prepared. The documentation and drawings will be reviewed to ensure that the final design meets the following requirements to ensure experiment hardware optimization:

a. Maximum reliability

b. Minimum cost

c. Minimum production time

d. Properly functioning design

The tests to be conducted in the Preliminary Design, Development, Test, and Evaluation Plan include only that testing to be conducted on other than flight hardware. These tests requirements can be grouped into three general categories: development testing, reliability testing, and qualification testing. In general, reports will be prepared as each test is completed, detailing the measured inputs, corresponding outputs, and all other test results. The final and baseline test results will be compared and any recommended design improvements or modifications documented.

31.2.1.1.1 Development Testing

Development testing includes all tests required to determine and verify the feasibility of the design approach, and tests necessary to evaluate the performance of the experiment hardware. Development testing will be done on other than flyable hardware which represents the actual flight hardware as closely as possible. To ensure adequate test performance of the prototype hardware, the criteria for testing, design requirements, and performance requirements must be compatible. Design improvements resulting from the evaluation and analysis of the test results will be introduced into the design as soon as possible. A reporting and documentation scheme will be established to ensure that all failures are explained and the necessary corrective action is taken.

31.2.1.1.2 Reliability Testing

Reliability testing includes those tests necessary to ascertain that the experiment will perform as intended for the mission duration. Both the experiments and subsystems share the problem of attaining extremely high reliability requirements, as do all other elements of the OTAES spacecraft. To ensure that all experiment hardware meets these standards, special reliability tests will be conducted on all critical items and equipment that have demonstrated marginal reliability.

31.2.1.1.3 Qualification Testing

Qualification testing includes those tests necessary to demonstrate that the hardware design specifications are adequate when the hardware is subjected to the intended environment. Where possible, development and qualification tests will be conducted on the same test article.

The Preliminary Design, Development, Test, and Evaluation Plans, including cost and schedules, as presented in the following individual experiment group plans, are based upon the completion of all detailed design, specification preparation, documentation, checkout, and special test equipment design and procurement necessary to complete the experiment development. All activity is to be completed in 41 months at a total cost of $5.31 million. A detailed cost and scheduling breakdown may be found in the individual experiment group plans.

31.2.1.2 Laser Group - Preliminary Design, Development, Test, and Evaluation Plan

31.2.1.2.1 General

This plan encompasses the design, development, and test of all prototype and space-borne equipment for the Laser Group of experiments and the required telescopic ground arrays. A Gantt Chart presentation of the Preliminary Design, Development, Test, and Evaluation Plan (DDT&E) is given in figure 31.2.1.2.1-1. As shown, the space-borne equipment listed for the precision

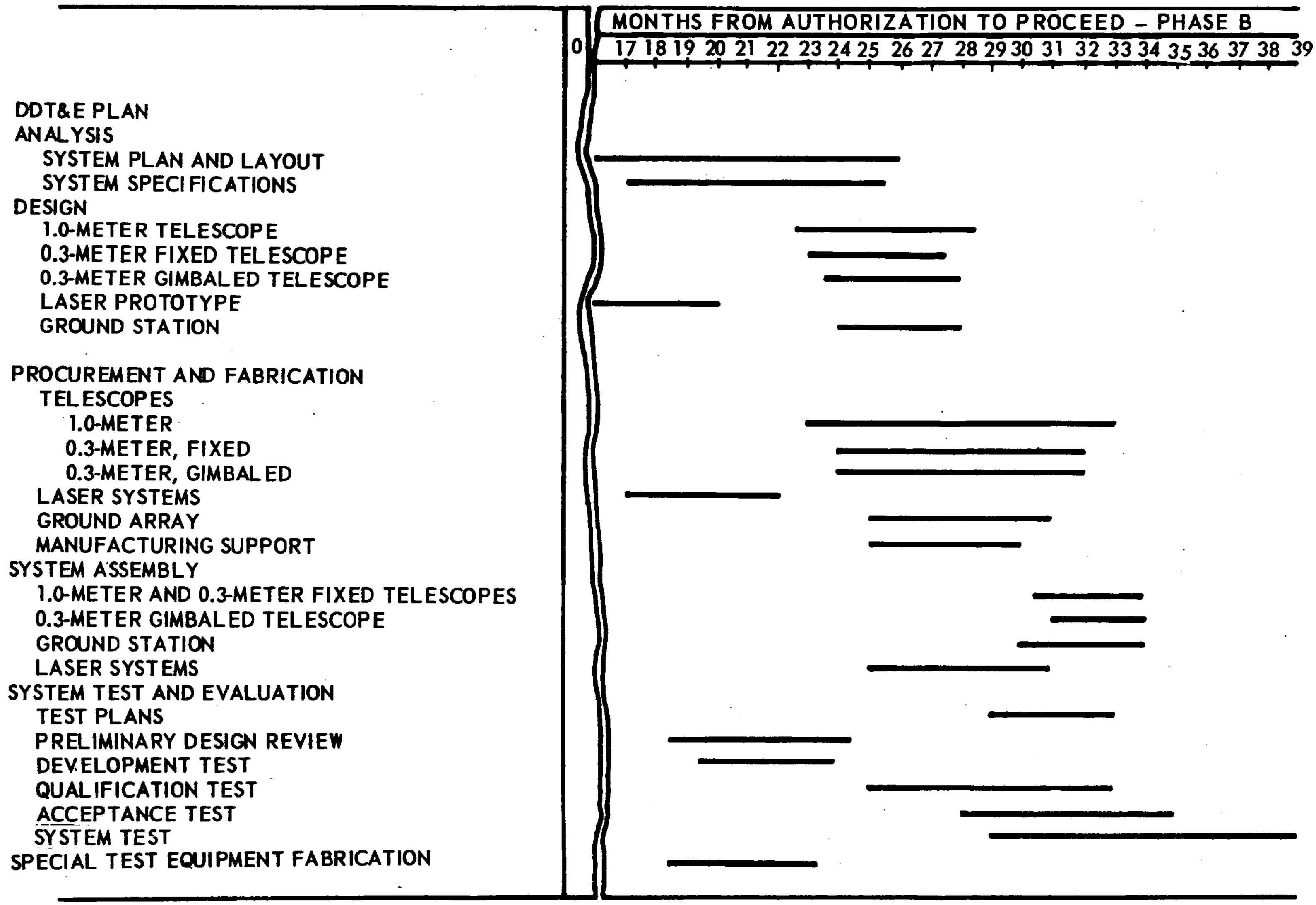

Figure 31.2.1.2.1-1. Laser Group Preliminary DDT & E Schedule

tracking, point ahead and loop closure, and transfer tracking experiments consists of the 1.0-meter telescope and an attached 0.3-meter telescope, and the 0.3-meter gimbaled telescope. In addition, one ground station is required for the precision tracking experiment, and two ground stations (i.e., one additional) for the point ahead and transfer tracking experiments.

31.2.1.2.2 System Analysis

31.2.1.2.2.1 System Plan and Layout

The complete system design for the Laser Group of experiments will be reviewed and updated. An equipment layout will be prepared. The systems design will be updated to increase performance and to meet any new requirements that may be imposed as a result of continuing studies.

31.2.1.2.2.2 Preliminary Design Reviews/Subsystem Specifications

The system design and analysis effort will result in detailed subsystem specifications and supporting documentation which reflect the complete design task as it is visualized by all development disciplines. At this point, the following information should be available for review:

a. System specifications

b. Detail subsystem design requirements

c. A detailed block diagram of the initial concept of each subsystem design solution

d. Basic mechanical package layouts depicting provisions for mounting, cabling, isolation, shielding, etc.

e. Initial tabulation of all interfaces

f. A performance analysis

g. An operational analysis

h. System test objectives

With the completion of the preliminary design review, the system will be released for development. The system release creates a change in emphasis from analysis and specification preparation to detailed design and development.

31.2.1.2.3 Detailed Design

31.2.1.2.3.1 Equipment

This equipment consists of laser tubes, telescope structure, the 1-meter primary mirror, the secondary mirror auxiliary optics electronic and electro-mechanical assemblies, and all mounting assemblies. Preparation of the detailed layout and assemblies for the primary mirror will begin immediately after the telescope layout is firm. Layout and assembly drawings, and circuit diagrams for the remaining components will be prepared in a parallel effort. As the component designs become firm, parts and materials will be selected, and procurement specifications prepared. Fabrication of breadboards is not included. Breadboards fabricated during the Prerequisite Technology phase will be available for modification and testing if significant design changes require early design tests.

31.2.1.2.3.2 Ground Stations

Two items of each laser system will be built. The prototype unit will be used for qualification testing then refurbished for use as a backup unit. A production unit will be built to serve as the primary operating equipment. One unit of the laser telescope and interferometer will be made. These units will be refurbished after test, for operational use. Quantities to be produced are:

UNIT	PROTOTYPE	PRODUCTION
He-Ne Transmitter	1	1
CO_2 Transmitter	1	1
He-Ne/CO_2 Receiver	1	1
Tracking Telescope	-	2
Argon Transmitter	1	1
Optical Interferometer	-	1
High PRF Gate Monitor Console	-	1

The laser transmitting/receiving equipment discussed here consists of the laser tube, its supporting electronics and immediate optics. Two interfaces are required with the Lasers. The tracking telescope, its optics and its pointing mechanism represent one interface. The other interface will be the Optical Technology Test and Operations Station (OTTOS) which will provide control and signal processing.

During this phase of the program the large-aperture receiver will be designed. Because a 3-meter-aperture receiver will be built and tested during the Prerequisite Technology phase, no development or testing of this receiver will be required in the Detailed Design Phase.

The ground array, in the present conception, contains 16, 5-inch-diameter telescopes, in a mount which permits accurate adjustment and boresight alignment of each telescope. The design, fabrication, and test of the array are independent of the corresponding phases of the space-borne telescopes, and could be shifted in time to provide an earlier or later completion date.

Layout and assembly drawings, selection of parts and materials, and preparation of procurement specifications for the telescopes, the auxiliary optics, and the mounting devices will be completed in this phase. The design efforts of the Laser Contractor, Telescope Contractor, and Prime Contractor will be closely coordinated and defined by subsystem interface specifications.

31.2.1.2.4 Fabrication and Development

31.2.1.2.4.1 Prototype Laser Development

The first of each of the three prototype laser systems will be an advanced engineering model. The breadboard models developed in the prerequisite technology phase will have progressed to a preliminary engineering model. This engineering/prototype model will provide preliminary system parameter measurements along with weight and center-of-gravity measurements. After preliminary measurements, this unit will be delivered to the Telescope Contractor for use in systems integration.

The second and third prototype models will be produced simultaneously. They will include all engineering changes. One model will be used for formal space qualification measurements, and the other model will be shipped to the Telescope Contractor in exchange for the engineering/prototype model. The engineering/prototype model will be updated with all changes and used as a laboratory test model to support qualification testing and design refinements.

Development of the first prototype unit will be accomplished in the laboratory by the respective design groups. Laser tubes, optical modificators, and optics will be produced by the Optical Systems department. Electronic engineers will produce all associated electronics, and mechanical engineering will produce ruggedized structures.

Electronic and mechanical production for the second and third prototype laser systems will be performed by the fabrication and assembly shops under the direction of product engineering.

31.2.1.2.4.2 Prototype Telescope Components

The primary and secondary mirrors for the space-borne telescopes are the long-lead items with the greatest time span of all the telescope components. In particular, the 1-meter primary mirror will require the longest time span for fabrication, and will, therefore, start first. As soon as the system design is sufficiently firm, mirror blanks for the 1-meter primary, and then the two 0.3-meter primaries, and the three secondaries will be ordered. During manufacture of the mirror blanks, they are thermally cycled for stress relief. The blanks are rough machined, ground, and coated with kanigen. The mirrors are then polished, aluminized, and coated with magnesium fluoride. During these phases, the mirrors will be optically checked to monitor the figure.

The other auxiliary optical, structural, electronic, and electromagnetic components will be fabricated during this time span. The effort on the electronic and electromagnetic components includes assembly of the component parts into modules or subassemblies, and culminates in their inspection and test.

31.2.1.2.4.3 Telescopic Array for Ground Stations

The procurement and fabrication on this effort will encompass all parts required for both ground stations.

31.2.1.2.4.4 Manufacturing Support

This phase will encompass the design and fabrication of the requisite tooling, jigs, fixtures, and special checkout equipment used in the fabrication and assembly of the prototype components and the ground stations. Manufacturing or operations sheets will also be prepared in this effort.

31.2.1.2.5 System Assembly

The assembly of the 1 meter and 0.3 meter fixed telescopes will be an integrated activity because of the common structure. The mountings for the optical, mechanical, and electronic assemblies of the telescopes will be assembled into the telescopes' structure; this will include the laser components and related assemblies, which are furnished by the Laser Contractor. The mirrors and other components will then be mounted and aligned; these operations will be completed on an optical bench, using the components outputs as well as optical sighting to align and checkout the components.

31.2.1.2.6 System Test and Evaluation

31.2.1.2.6.1 Test Plans, Procedures, and Fixtures

This effort will encompass all testing planned for the lasers and prototype telescopes, and the functional and environmental testing to be performed on the ground telescopic array before its integration with the remaining ground station equipment. Test plans, detailed test specifications, and procedures will be prepared during the fabrication phase. This effort will also include the design and fabrication of test equipment and fixtures for the telescopes and laser, and any simulators required to provide signal inputs.

31.2.1.2.6.2 Development Tests

Component and subsystem tests will be accomplished by the respective design engineering department. Electromagnetic interference (EMI) and vibration tests will be performed by an environmental test group.

The subsystem specifications generated during the definition phase contain the basic test requirements for individual subsystems including acceptance, environmental, EMI, reliability, life and special evaluation testing. These test requirements will be reflected in test procedures written by the subsystem engineers.

31.2.1.2.6.3 Systems Tests

Systems testing will be directed at those tests that involve more than one subsystem. The Systems Test department will write the systems test plans and procedures.

31.2.1.2.7 Cost and Schedules

The Preliminary Design, Development, Test, and Evaluation cost for the Laser Group of experiments is estimated to be $2.0 million. The Preliminary Design, Development, Test, and Evaluation effort is to be completed in 39 months from Authorization to Proceed-Phase B as shown by the Gantt Chart, figure 31.2.1.2.1-1.

31.2.1.3 Large Optics Group - Preliminary Design, Development, Test, and Evaluation Plan

31.2.1.3.1 General

This plan encompasses the engineering effort for the Large Optics Group of experiments, which commences upon completion of the prerequisite technology phase, and includes design, prototype procurement and fabrication, prototype system assembly, and testing.

No breadboards or mockups are required, since these will be completed in the prerequisite technology phase. Other portions of the total engineering effort are described in the Manufacturing, Test, and Facility Plans. The time requirements for each activity have been reduced to provide the earliest possible launch with minimal technical compromise. An overall summary of the efforts involved showing projected time spans is given in figure 31.2.1.3.1-1. The coding used indicates those time span portions which are separable for either the thin or active mirror experiment only. All other time spans depict either one single effort applicable to both experiments (e.g., interferometer design) or two parallel but independent and analogous efforts (e.g., primary mirror design).

31.2.1.3.2 System Analysis

31.2.1.3.2.1 System Plan

A system plan will be prepared for each mirror experiment. The system analysis will include all flight subsystems, such as primary and secondary mirrors, structure, thermal actuators and controls, pneumatic bladder for primary mirror suspension and protection during launch, and optical instrumentation including scatter plate interferometer.

31.2.1.3.2.2 Subsystem Specifications

Power and weight requirements will be allocated to each portion of the system. The subsystem interfaces and characteristics (e.g., power and signal inputs/outputs) will be defined quantitatively, error analysis will be performed and tolerances established for each parameter, and a design specification will

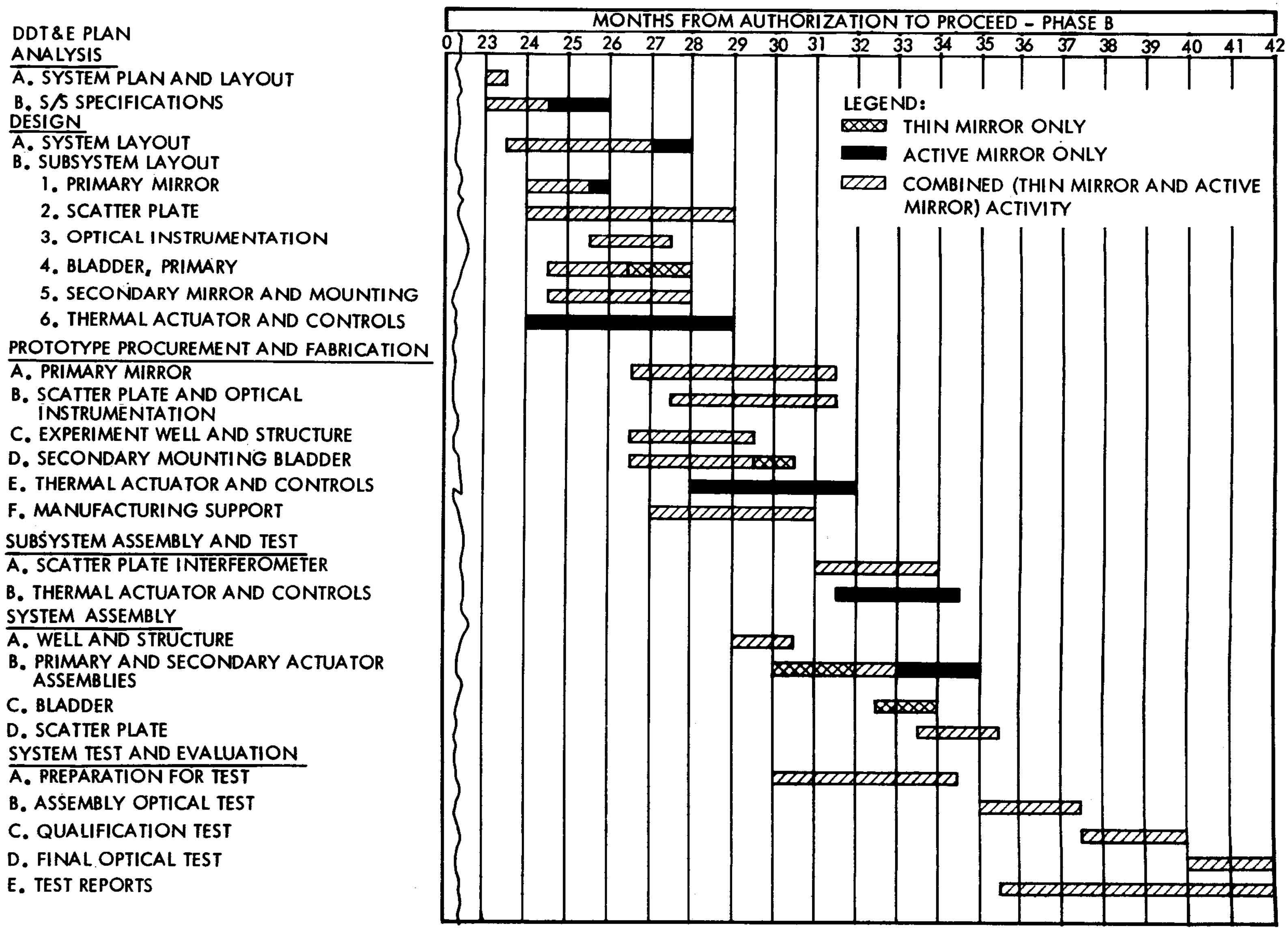

Figure 31.2.1.3.1-1. Large Optics Group Preliminary DDT & E Schedule

be prepared for each subsystem.

31.2.1.3.3 Detailed Design

31.2.1.3.3.1 Layout

The layout for the Large Optics Experiment Group will be prepared within the spacecraft constraints of volume and weight. Applicable system detail drawings (for the well structure and subsystem housings, for example) will be prepared. Detail design for packaging and mounting of each subsystem will be performed concurrently.

31.2.1.3.3.2 Subsystem Schematics and Layout Drawings

31.2.1.3.3.2.1 Primary Mirror Assemblies

The layout for the two primary mirror assemblies will be developed first, since the primary mirror has a relatively long fabrication time. An extensive design effort is required for the engineering analysis, drawings, and specifications for the primary mirror. However, a full size primary mirror is scheduled to be designed, manufactured, and tested during the prerequisite technology phase; consequently, only an update of the primary mirror (and nest) design will be required. Since the nest will be used to support the blank for the thin primary mirror during fabrication, the design updating for the nest and the preparation of drawings and specifications will proceed in parallel with the primary mirror effort. Engineering checking of the primary mirror and nest design, drawings, and specifications will be continuous. A final engineering check and design review will be completed and documented.

31.2.1.3.3.2.2 Scatter Plate Interferometer

The design of the scatter plate interferometer will start simultaneously with that of the primary mirror assemblies because of an anticipated long design phase for the photographic and electronic data processing portion of the interferometer equipment. The engineering and design efforts on this equipment can proceed almost independently of the primary mirror and nest design until the last phases of detailed system layout. Completion of electronic data processing assembly schematics will be the first milestone of this effort. The circuits will be analyzed, stresses determined, and parts selected. The preparation of part and material procurement specifications will begin along with the detailed layout and assembly drawings for remaining portions of the interferometer subsystem (scatter plate, laser light source, and auxiliary optical components). Design review of the electronic packages and engineering checkout of all interferometer design drawings will be completed and documented.

31.2.1.3.3.2.3 Additional Spaceborne Optical Instrumentation

The design effort for the additional spaceborne optical instrumentation, the Foucault knife-edge tester, will be phased in toward the end of the scatter plate interferometer effort. The tester will be interchangeable with the interferometer and mounting methods and packaging will be analogous. This phase will also include design of a space-qualified auto-collimator.

31.2.1.3.3.2.4 Primary Mirror Mounting and Pneumatic Bladders

Layout and design of the primary mirror mounting and the pneumatic bladders which support the thin mirror during launch will be closely integrated. These efforts will begin as the design effort for the primary mirror and nest passes its peak. After completion of the layout, engineering checkout will be performed and detailed fabrication and assembly drawings will be prepared.

31.2.1.3.3.2.5 Secondary Mirror, Tripod, and Mounts

The detailed layout of the secondary mirror and its erectable tripod and mounts will begin as the primary mirror and nest design effort phases out. Because of the shorter design and fabrication time spans required, the layout can be completed and checked, and the detailed drawings and procurement specifications prepared, while the primary mirror is being fabricated.

31.2.1.3.3.2.6 Thermo-Mechanical Actuators and Controls

The thermo-mechanical actuators and controls system is the most complex subsystem and will have the longest design time. This subsystem consists of the mechanical actuators and their heaters and temperature sensors and the reference plate and their electronic subassemblies. Also included in this group, because of similarity, are the heaters and sensors applied directly to the primary mirror. The subsystem layout will begin with the primary mirror layout. Then the detailed assembly drawings for the mechanical subassemblies and the circuit diagrams for the electronic modules will be prepared. Parts and materials will be selected and procurement specifications prepared. Engineering checkout and design review will be continuous and will be completed and documented at the end of this effort.

31.2.1.3.4 Fabrication and Procurement of Prototype Components

31.2.1.3.4.1 Primary Mirrors and Mirror Nest

Only flight article primary mirrors will be manufactured during this program. The 1.27-meter models previously manufactured will serve as the primary mirrors for the prototype system. The figure test data previously taken upon completion of the manufacturing operations (with the thin mirror in its nest) will also be used in this program, constituting prototype system optical baseline data.

31.2.1.3.4.2 Scatter Plate Interferometer and Optical Test Instrumentation

The pacing item in this phase will be the electronic scanning and data processing equipment. As in the prerequisite technology phase, presently available equipment and components such as Kodak's high resolution picture transmission system designed for the Lunar Orbiter, will be adapted to the maximum extent. The scatter plate, laser light source, and photographic components will also be purchased state-of-the-art equipment, with redesign of mountings and adjustment devices to meet the requirements of the experiments. The fabrication of the beam-splitters, image-forming telescopes, and other auxiliary optical devices for the interferometer and the Foucault tester's components will also be completed in this phase.

31.2.1.3.4.3 Well Structure and Housings

The fabrication of the well for the two mirror experiments will begin as soon as firm design information is generated. This effort will include the hatches, the sealed optical ports through which the testing is performed, and the mounting and attachment points for all contained components.

31.2.1.3.4.4 Primary Mounts, Secondary Mirror and Mounts, Pneumatic Bladder

The procurement of these components, starting with the long lead items, will begin as soon as firm designs and drawings are available for the piece parts and will be completed in this phase. The fabrication of the secondary mirror and all mounts will follow methods employed previously. The pneumatic bladder and the bladder's valve fabrication methods will be determined concurrent with the design effort. The bladder will undergo testing as part of its fabrication phase.

31.2.1.3.4.5 Thermo-Mechanical Actuators and Controls

Because of the long design time, this subsystem's fabrication will start last, beginning with procurement and fabrication of piece parts as soon as firm design drawings are available. This effort will encompass fabrication of the electronic and mechanical subassemblies, including the mirror heaters and sensors. The subsystem then requires a separate assembly and test effort except for the mirror heaters and sensors, which will be available for assembly to the mirror structure upon completion of this phase.

31.2.1.3.4.6 Prototype Manufacturing Support

The requirements for manufacturing tooling, jigs, fixtures, and special checkout equipment for both the primary mirrors and the nest will be determined by the contractors who fabricate and procure prototype components. A table capable of holding a 1.27-meter mirror during fabrication is not available at all the contractor facilities considered. The table will be rented during fabrication, and the cost is included in the primary mirror and nest fabrication effort. The contractor will also supply optical test equipment used during manufacture.

The required manufacturing support for the subsystems will encompass the design and fabrication of the required tooling, jigs, and fixtures. Manufacturing or operations sheets and inspection test procedures will be prepared. Any special test or checkout equipment required for subassembly fabrication will be purchased or fabricated in this phase.

31.2.1.3.5 Subsystem Assembly and Test

31.2.1.3.5.1 Scatter Plate Interferometer

The scatter plate interferometer, with its photographic and electronic assemblies, requires a subsystem assembly and testing effort. The experiment well and its components will be assembled separately in a parallel effort. The laser source, scatter plate, and the auxiliary optics will be assembled and a visual check and alignment of the assembly performed. Then the photographic ane electronic subassemblies will be integrated and, using a standard test mirror, test interferograms will be taken. All interferometer components will be properly aligned in their housings and a complete functional test performed. The interferometer will then be available for prototype system integration.

31.2.1.3.5.2 Thermo-Mechanical Actuators and Controls

The assembly of this subsystem will proceed in parallel with and independently of the start of system assembly. The reference plate, actuators and actuator heaters, and electronic assemblies will be integrated and then adjusted and tested with a suitably thin plate substituting for the primary mirror. (The technique will be developed during the prerequisite technology phase). The test will then be re-run with the electronic assemblies, actuators, and simulated mirror placed in a thermal-vacuum chamber. Upon completion of this test, the plate will be removed and the subsystem will be integrated with the prototype active mirror. Optical testing will be performed after the mirror and actuator subsystem is assembled into the experiment well, as part of the system optical baseline test.

31.2.1.3.6 Prototype System Assembly

31.2.1.3.6.1 Experiment Well and Structure

The hatch, subsystem housing, mounting points, and optical port will be assembled to the well structure and properly aligned. All assemblies and alignments will be inspected for conformance to required dimensions and tolerances.

31.2.1.3.6.2 Primary and Secondary Mirrors, Mounting Structure, and Actuator Assembly

The mounting structure for the mirrors will be assembled to the well structure before completion of the previous phase. The active mirror, actuator assembly, and the thin mirror, without the nest, will then be mounted and aligned. This assembly and alignment will be done on an optical bench, using reference mirrors and optical sightings with auto-collimators. Final adjustments will be performed later when the Foucault Tester and interferometer are available.

31.2.1.3.6.3 Pneumatic Bladder

The pneumatic bladder will be assembled to the thin mirror well of the prototype system. After checking, it will be deflated to allow for further optical tests.

31.2.1.3.6.4 Scatter Plate Interferometer and Foucault Tester

After completion of the prototype assembly, and the interferometer subassembly and test, this system will be mated to the optical instrumentation points outside the experiment well. Although no accurate information can be obtained on the thin mirror's figure during ground test, the interferometer will be exercised through all modes of data collection after separation from its nest. This will include direct visual examination of the primary mirror surface with the interferometer, and photographic and electronic interferogram data taking. The Foucault Tester will also be mounted and exercised. Final alignment of the optics will be performed using these subsystems, reference mirrors, and an autocollimator and all alignment data will be recorded.

31.2.1.3.7 Prototype System Test and Evaluation

31.2.1.3.7.1 Testing Program, Plans, and Fixtures

Test program plans and detailed test specifications and procedures for the prototype system will be prepared starting during the equipment fabrication phase. This phase also includes the design and fabrication of test instruments and fixtures, including an auto-collimator, several reference mirrors, and testing fixtures and instrumentation.

31.2.1.3.7.2 Prototype System Optical Baseline Test

Upon completion of the prototype assembly, a complete optical test of the system will be performed. This test will be the baseline from which to evaluate the results of the qualification testing. It will permit determination of any component mounting shifts, misalignments, or major mirror distortions that may occur. The measurements recorded using the scatter plate interferometer and Foucault Tester will be part of the required data. The thin mirror figure test will also constitute baseline test data, although it will be used for comparison with figure data taken in space, rather than during ground tests. This is because thin mirror figure data is not meaningful once the nest is removed, except in space. This test will encompass interferograms, photographs, and visual evaluation of the figure, using a Foucault tester and a scatter plate interferometer. The breadboard interferometer from the pre-requisite technology phase will be available in case the prototype subsystem is not ready.

For the active mirror experiment, the baseline test will consist of assembly and alignment measurements and figure measurements of the mirror taken after manufacture and when fully assembled inside the experiment well. The actuators will be exercised to counter balance gravity effects on the primary mirror in several orientations, such as horizontal and vertical. In addition, thermal gradients will be deliberately introduced, using the primary mirror's heaters, sensors and the actuators operated to correct the resultant distortion. Finally, the actuator mirror assembly will be calibrated by activating

activating one and then groups of actuators, and recording the output as a function of the position of and input to the active actuators. Upon completion of all optical testing and recording data, the assembly will be ready for qualification testing.

31.2.1.3.7.3 Qualification Testing

The prototype system's bladder will be inflated and all components put into prelaunch configuration (i.e., the secondary mirror mounting collapsed to the side, and the scatter plate interferometer, Foucault tester, and other removable instrumentation taken off for stowage). The experiment well will then be mounted into its test fixture and exposed to the following environments: shock, along the thrust and two mutually perpendicular axes; random vibration, same three axes; and acceleration, along the thrust axis (lateral acceleration levels are generally too low to have significant effect after the vibration test). The test inputs will be designed to simulate launch environment, with the levels increased above that expected to prove a sufficient margin of safety. Visual checks for deterioration will be made after each exposure.

The interferometer, Foucault Tester, and other stowed instrumentation will receive the same dynamic tests, but in a fixture which simulates the stowed conditions of launch. In addition, these components will be subjected to operating temperature tests at levels simulating high and low extremes expected, plus a safety factor. The bladder, inflated and in a simulated loaded condition, will be tested for survival in a high vacuum at the completion of its fabrication phase. Similarly, the active mirror-actuator assembly will complete thermal vacuum exposure during its assembly and test phase.

31.2.1.3.7.4 Final Prototype Optical Test

A complete optical test will be performed upon completion of the qualification testing. For this test, the interferometer and Foucault Tester will be checked for misalignment. It will then be removed and tested individually, and remounted to the experiment well. A complete prototype system test will subsequently be performed. All measurements of alignments and mounting adjustments made previously will be repeated and recorded. Figure test of the active mirror will be repeated and a limited check of the actuator system calibration performed. All other subsystems will be exercised and, if necessary, removed for detailed examination.

31.2.1.3.7.5 Test Analysis and Reports

Reports will be prepared as each optical, functional, and environmental test is completed, recording inputs and results. The results of the final test will be compared to the baseline data, and recommendations for any desirable design modifications to the flight article system will be made. Finally, recommendations will be prepared for refurbishing and updating the prototype system to flight article status.

31.2.1.3.8 Cost and Scheduling

The Preliminary Design, Development, and Evaluation cost for the Large Optics

Group of experiments is $1.19 million. The Preliminary Design, Development, Test, and Evaluation effort (figure 31.2.1.3.1-1) is to be completed in 41 months from the authorization to proceed with Phase B.

31.2.1.4 Fine Guidance and Isolation Comparison Group - Preliminary Design, Development, Test, and Evaluation Plan

31.2.1.4.1 General

This plan encompasses the engineering effort which begins upon completion of the prerequisite technology phase, including design, prototype procurement and fabrication, prototype system assembly, and testing. The effort described by this plan applies to the Fine Guidance and Isolation Comparison Group of experiments, experiments 12 and 13.

The fine guidance equipment has been grouped into four major subsystems: the telescope, including structure and optics; the coarse/intermediate pointing, including the astro-trackers and the control moment gyros used for actuation; the fine pointing; and the protect subsystem. The equipment for the Comparison of Isolation Techniques experiment has been grouped into three major subsystems: the hardmount, including the gimbals and other components required for the operation of a gimbaled telescope hardmounted to the spacecraft; the soft suspension, which includes both the springs, magnets, and auxiliary support subsystems required for the soft mode of operation; and the servo-suspension, which includes the magnets needed for the soft mode of operation, the accelerometer, the servo-electronics, and the rigid structure for a three-axis suspension.

Every effort has been made to reduce the time requirements for each activity and the overall time span. It is planned to start procurement of the optics and other long lead items early in the design phase.

31.2.1.4.2 System Analysis and Specifications

A system plan for each experiment will be prepared to establish the design parameters for all components and subsystems and the constraints imposed by the spacecraft and mission.

All subsystem interface parameters (e.g., signal inputs and outputs) will be established analytically and experimentally. From these relationships and the spacecraft and mission constraints, the design parameters, weight and volume constraints, power considerations, and mounting and attachment data can be determined. Error analysis will be performed, tolerances will be established for each parameter, and subsystem specifications will be prepared. This will be a continuing effort throughout the design phase.

31.2.1.4.3 Detailed Design

The development of subsystem schematics and system layout drawings for the Fine Guidance and Isolation Comparison Experiment Group, from which the components and subassemblies can be fabricated by the contractors or by selected vendors, will be the scope of this effort.

31.2.1.4.3.1 Telescope Structure and Optics

This subsystem encompasses the primary and secondary mirrors, their mountings, and the structure of the telescope. The onboard star simulator is also included as a component of this subsystem. Engineering checkout of the design will be parallel with design, and a final check and design review will be documented at the conclusion of this effort.

31.2.1.4.3.2 The Coarse/Intermediate Pointing Subsystem

This system is composed of four parts:

a. Astro-trackers for coarse error sensing.

b. Actuators and control moment gyros, which null out both the coarse and intermediate error signals.

c. The intermediate error sensor, including its auxiliary optics, and a microscope.

d. The required electronic and electro-mechanical assemblies, such as the logic circuits, motors, and amplifiers.

The design of the astro-trackers and the actuators is a major portion of this effort, and both are long lead components. Therefore, design of these components is begun immediately after the subsystem layout is completed. The control moment gyro design will be subcontracted and the other assemblies will be completely designed by the Fine Guidance Contractor. Preparation of the envelope drawings and purchase specifications for the control moment gyros will be completed first. Preliminary assembly layouts will be prepared for each remaining component and schematics will be drawn. The circuit designs will be reviewed and all stress and application factors computed. Finally, parts will be selected and procurement specifications prepared. Fabrication of breadboards will not be required, but modification and testing of breadboards fabricated during the prerequisite technology program will be performed, as required by design changes, during the final portion of this design effort.

31.2.1.4.3.3 Fine Pointing Subsystem

This subsystem consists of the following subassembly groups:

a. The diasporameter fine pointing deflector.

b. A cantilevered mirror fine pointing deflector.

c. The crossed axis reed fine error sensor.

d. The pyramid prism fine error sensor, including auxiliary optics and a microscope.

e. The required electronic and electro-mechanical assemblies.

The first four assemblies consist of two complete and independent units for deflection and sensing. This is for evaluation of alternative designs and for redundancy. The preparation of layouts, schematics, and procurement specifications will proceed in parallel with items a, c, and d of paragraph 31.2.1.4.3.2, but independently, except for the electronic and electro-mechanical subassemblies, which will benefit from common design. Previously fabricated breadboards will be used.

31.2.1.4.3.4 Protect Subsystem

This subsystem encompasses two assemblies: the protect sensor, to detect high light levels coming into the telescope's field, and the protect actuator, which will stop light from entering the error sensors.

This subsystem is less complex than those previously discussed. The start of this design effort will follow initiation of the electronic subsystem effort, and each design phase, although similar, will be shorter.

31.2.1.4.2.5 Hardmount

This subsystem is comprised of the inner gimbal ring, the outer gimbal(suspension) ring, the bearings and torquers, the caging mechanism, the angle pickoffs, and the data couplers. The gimbal bearings and caging mechanism will be designed by the Comparison of Isolation Techniques experiment Contractor. Design of the other components will be subcontracted to selected vendors.

31.2.1.4.3.6 Soft Suspension

This subsystem is composed of the springs and electromagnets, the sensing and drive electronics for the electromagnets, the damping mechanism, and the power and data couplers. These items will be designed by the Comparison of Isolation Techniques experiment Contractor.

31.2.1.4.3.7 Servosuspension

This subsystem is composed of the position sensing electronics, the accelerometer, the servo-electronics, and the suspension structure. The accelerometers will be subcontracted to selected vendors, the other items will be designed by the Comparison of Isolation Techniques experiment Contractor.

31.2.1.4.4 Procurement and Fabrication of Prototype Components

31.2.1.4.4.1 Telescope Structure and Optics

This subsystem, having the longest span in this phase, will be started first (with the ordering of the primary and secondary mirror blanks). The two mirrors and most of the telescope structure will be fabricated at selected vendors' facilities. The fabrication phases for the mirrors are similar to those described for the Laser Group of experiments. This phase will culminate with the assembly and checkout of the optics in the telescope structure.

31.2.1.4.4.2 Coarse/Intermediate Pointing Subsystem

This phase will begin with the fabrication of the subsystem's longest lead item, the control moment gyros, by the selected Subcontractor. Since the reliability requirements for the motors and the electronic parts will be stringent, most of these items will have long lead times and will be purchased as early as possible. This phase will conclude with the fabrication of the electronic modules or subassemblies, including inspection and testing to each module's specifications.

31.2.1.4.4.3 Fine Pointing Subsystem

Beginning with the ordering of parts, procurement, fabrication, and inspection and testing of all modules and subassemblies, this effort will proceed in parallel with the phases discussed above. Each subsystem effort will be independent, except for the subassemblies noted previously (see paragraph 31.2.1.4.3.3).

31.2.1.4.4.4 Protect Subsystem

As previously noted, the reduced complexity of this subsystem will allow initiation of this effort following the ordering of parts for the other subsystems. Each phase of this effort will be similar to those described for the electronic subsystem, but shorter.

31.2.1.4.4.5 Hardmount

Procurement will start as soon as the first detail drawings are completed and will continue until the gimbals, which are the pacing items, have been designed and fabricated.

The gimbals and caging mechanism will be fabricated in-house and the other items let out to vendors.

31.2.1.4.4.6 Soft Suspension

Most components of this subsystem will be fabricated in-house. Fabrication will start with detailed definition of the springs and continue through to fabrication of the power and data couplers, which may be procured from an outside vendor.

31.2.1.4.4.7 Servosuspension

The pacing items in this subsystem will be the accelerometers and servo-electronics.

31.2.1.4.4.8 Prototype Manufacturing Support

This phase includes the fabrication of tooling, jigs, fixtures, and special checkout equipment used in the fabrication and assembly of the prototype components, excluding the control moment gyros. Also included is the preparation of manufacturing instructions, or operations sheets, and modular and subassembly inspection and test procedures.

31.2.1.4.5 Subsystem Assembly and Test

31.2.1.4.5.1 Test Plans, Procedures, and Fixtures

Beginning early in the fabrication effort, test plans, detailed test specifications, and procedures will be prepared for the prototype subsystems. This effort also encompasses the design and fabrication of test equipment fixtures for the subsystems, including simulators to provide the required inputs and loads to each subsystem. The tests planned for this phase are detailed subsystem functional tests at room ambient conditions and during temperature and vacuum exposures. Dynamic tests will be performed on all subsystems.

31.2.1.4.5.2 Coarse/Intermediate Pointing Subsystem

The modules and subassemblies of this subsystem will be integrated for testing, beginning prior to the fabrication phase conclusion and concluding shortly after. A complete subsystem functional test will include introducing a simulated light source input to the trackers and varying its characteristics as the resultant output of the actuators, suitably loaded, is measured and recorded. The operation of the logic circuits in switching over to the intermediate sensor will be simulated, and the actuator performance measured and recorded. The microscope will be checked during the test, and all output and significant internal parameters (for example, intermediate sensor error signal output) will be measured and recorded. The subsystem will then be exposed to the planned thermal vacuum conditions and tested again.

31.2.1.4.5.3 Fine Pointing Subsystem

The assembly of this subsystem will proceed independently of, but in parallel with, the effort described above. The functional tests at room ambient and thermal-vacuum conditions will also be similar (i.e., a simulated light source will be used, and the inputs varied over the specified range, while all output parameters are measured and recorded). Measurement of the pointing accuracy and stability to the subsystem's specified tolerance is not possible during ground test. The best obtainable resolution would be achieved by testing on an air-bearing table. To save time, however, the air-bearing table will not be utilized for prototype testing; it will be part of the flight article acceptance tests. The prototype subsystem test plan will provide for separate coarse testing of the two alternate fine pointing packages. Then, by using each one as an output device while operating the other, additional and finer performance data for testing purposes will be obtained.

31.2.1.4.5.4 Protect Subsystem

Fabrication of this subsystem will be completed prior to the Coarse/Intermediate and Fine Pointing subsystems and will consequently be assembled for testing first. The complete functional test will require a simulated light source, and the intensity and angle off-axis will be recorded at the point where protect actuation is initiated. This subsystem will also receive thermal-vacuum exposure and, upon completion, will be the first subsystem assembled into the prototype telescope structure.

31.2.1.4.5.5 Hardmount

The hardmount assembly will start with the completion of the component procurement. After completion of assembly, the hardmount will be tested as a unit. The purpose of the tests will be to verify that the individual components, such as the caging mechanism, are functioning properly and that the subsystem as a whole meets the performance requirements in all experimental operational modes.

31.2.1.4.5.6 Spring/Gimbals Suspension

After completion of the hardmount tests, the entire hardmount system will be suspended by springs and retested. The tests will be identical to those of paragraph 31.2.1.4.4.3, with the exception that the test facility must provide for soft mount suspension and, in addition to performance tests, the acquisition phases of the experiment must be tested.

31.2.1.4.5.7 Magnetic Suspension

While the dynamic operational tests are performed on the spring gimbals, static tests will be performed on the magnetic suspension, using a separate test fixture. After static tests have been completed and isolation, damping, and rotational constraint performances are certified to meet the specification, dynamic tests of the magnetic suspension will be performed. This must await completion of the spring suspension test, as only one test fixture will be provided for dynamic tests.

31.2.1.4.5.8 Servosuspension

Static tests on the servoactuators will proceed simultaneously with the magnetic suspension static tests. At the completion of the magnetic suspension dynamic tests, the servosystem can be tested immediately by installing the additional components required for the servosystem directly onto the test subsystem, with no dismantlement of the test fixture.

31.2.1.4.6 Prototype System Assembly and Checkout

Starting with the protect subsystem, each subsystem will be assembled into the telescope structure. Alignment of each subsystem will be checked optically. The system will then be passed through its modes of operation, with the subsystem's outputs monitored, and alignments adjusted for maximum performance.

31.2.1.4.6.1 Testing Programs, Plans, and Fixtures

The system test program will be specified in detail, beginning in the fabrication phase. After the test program plan is determined, detailed system test plans and procedures will be prepared; simultaneously, the required test instruments, simulators, and fixtures will be designed and fabricated. This effort will make maximum use of the procedures and hardware of the subsystem test phase.

31.2.1.4.6.2 Prototype System Baseline Test

Upon completion of assembly and checkout, a complete functional test of the system will be performed, and all significant input and output parameters will be measured and recorded. The test will be based on the subsystem tests and will include, in addition, a complete record of the telescope's optical alignment and image quality (using photographs of the image, auto-collimation, knife-edge, and similar optical tests). This test will serve as the baseline for evaluation of any changes which may occur during the subsequent testing.

31.2.1.4.6.3 Qualification Testing

The prototype systems will be adjusted to prelaunch status and mounted to a fixture which will simulate the spacecraft's telescope mounting and isolation system. It will then be subjected to dynamic environmental tests such as shock, random vibration, and acceleration tests. The system will then be exposed to thermal environment, and limited functional testing of the subsystem performance will be performed. Visual checks for deterioration or damage will be made after each test.

31.2.1.4.6.4 Final Prototype Functional Test

A complete functional test, identical to the baseline test, will be performed upon completion of the qualification testing. The subsystems will be dismounted, and complete functional tests will be performed upon them separately if necessary for full information.

31.2.1.4.6.5 Test Analysis and Reports

Reports will be prepared as each optical, functional, and environmental test is completed, detailing the measured inputs, outputs, and all results. The results of the final system and subsystem tests will be compared to the baseline and pre-baseline subsystem tests. Any recommended design improvements or modifications will be developed and implemented on the flight article system. Recommendations will be prepared for refurbishing the prototype system to flight article status.

31.2.1.4.7 Cost and Scheduling

The Preliminary Design, Development, Test, and Evaluation cost for the Fine Guidance and Isolation Comparison Group of experiments is estimated to be $2.12 million. This effort, as shown in figure 31.2.1.4.7-1, is to be completed within 40 months after Authorization to Proceed - Phase B.

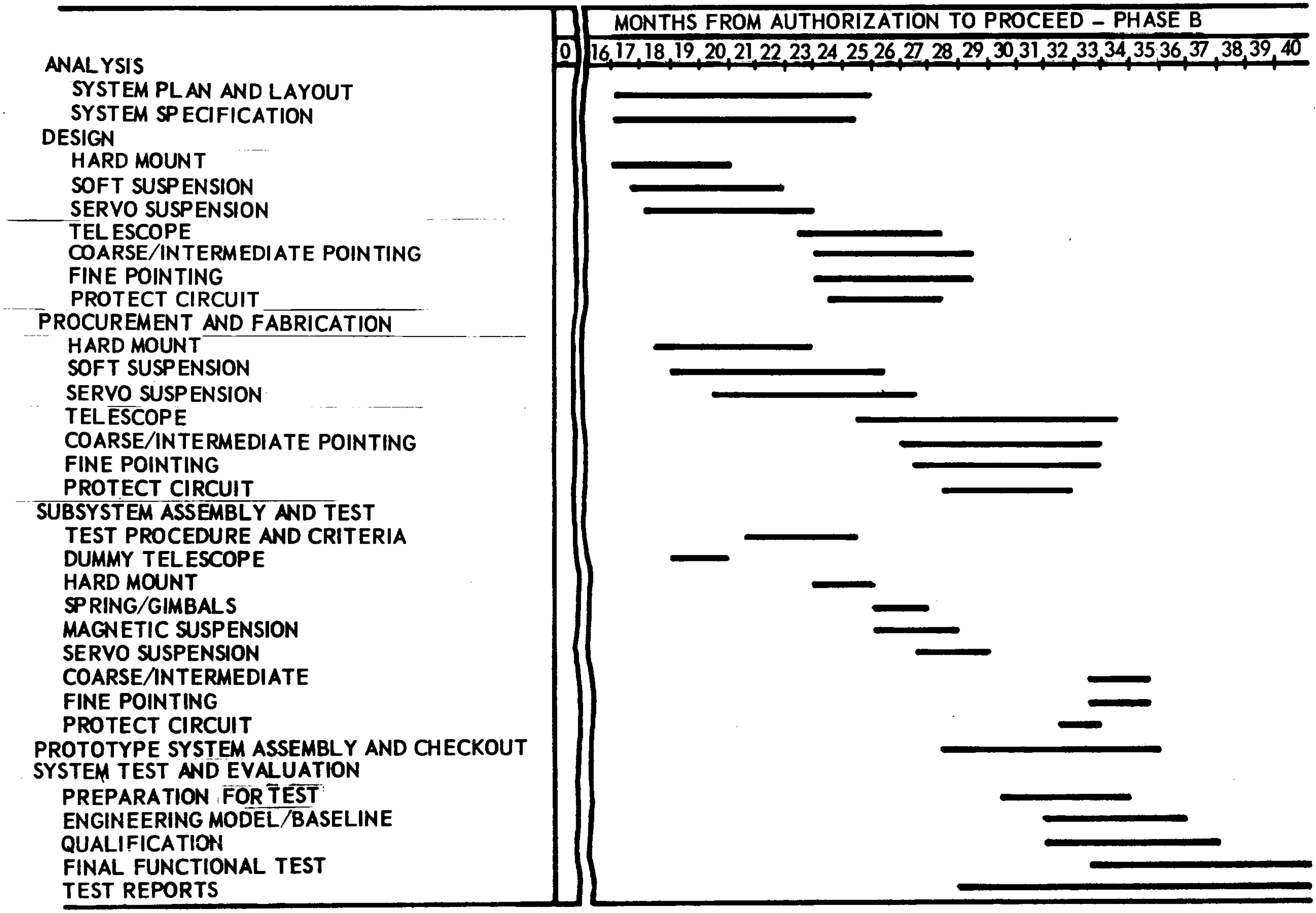

Figure 31.2.1.4.7-1. Fine Guidance and Comparison Group DDT & E Schedule

31.2.2 Preliminary Experiment Manufacturing Plans

31.2.2.1 Introduction

The experimental program set forth in the Preliminary Design, Development, Test, and Evaluation Plan will provide maximum technological and scientific information. This can best be learned from an orbit environment. The recommended experimental program will consist of 13 hardcore experiments, which have been further grouped into 3 major experiment categories: 1) Laser Group; 2) Large Optics Group; and 3) Fine Guidance and Isolation Comparison Group. Once the final design of the experiment hardware has been thoroughly evaluated and approved, the hardware will enter the manufacturing phase.

The manufacturing plan encompasses the fabrication and production of both flight and prototype hardware as well as any necessary ground support or special manufacturing equipment. The manufacturing effort will use existing as well as advanced procedures and techniques.

The manufacturing plan, where possible, will be fully integrated with the Preliminary Design, Development, Test, and Evaluation Plan; that is, manufacture of the flyable experiment hardware will begin before the completion of the prototype hardware, and run concurrently with the prototype assembly, test, and evaluation. The alternate approach of having the flyable experiment hardware manufacturing effort begin after the completion of the prototype hardware was rejected because of its substantially longer time span.

The Preliminary Design, Development, Test, and Evaluation Plan presented those tests conducted on other than flight hardware to determine design feasibility, hardware performance, and those tests necessary to demonstrate that the hardware specifications are complied with when subjected to the intended environment. The testing presented in this plan will be those tests necessary to assure continuity of engineering design requirements and in-process testing to assure adherence to specifications and workmanship requirements.

The manufacturing plans, including both cost and schedules, presented herein, cover all manufacturing efforts necessary to produce prototype and flight hardware. All manufacturing is to be completed in 48 months at a total cost of $7.75 million. Refer to the manufacturing plan of the individual experiment groups for a detailed cost and schedule breakdown.

31.2.2.2 Laser Group Manufacturing Plan

31.2.2.2.1 General

This plan encompasses the fabrication and production of both the prototype and flight hardware associated with the Laser Group of experiments. A summary of the manufacturing plan is presented in figure 31.2.2.2.1-1. Discussion of those activities presented will follow, referenced to pertinent aspects of the Preliminary Design, Development, Test, and Evaluation

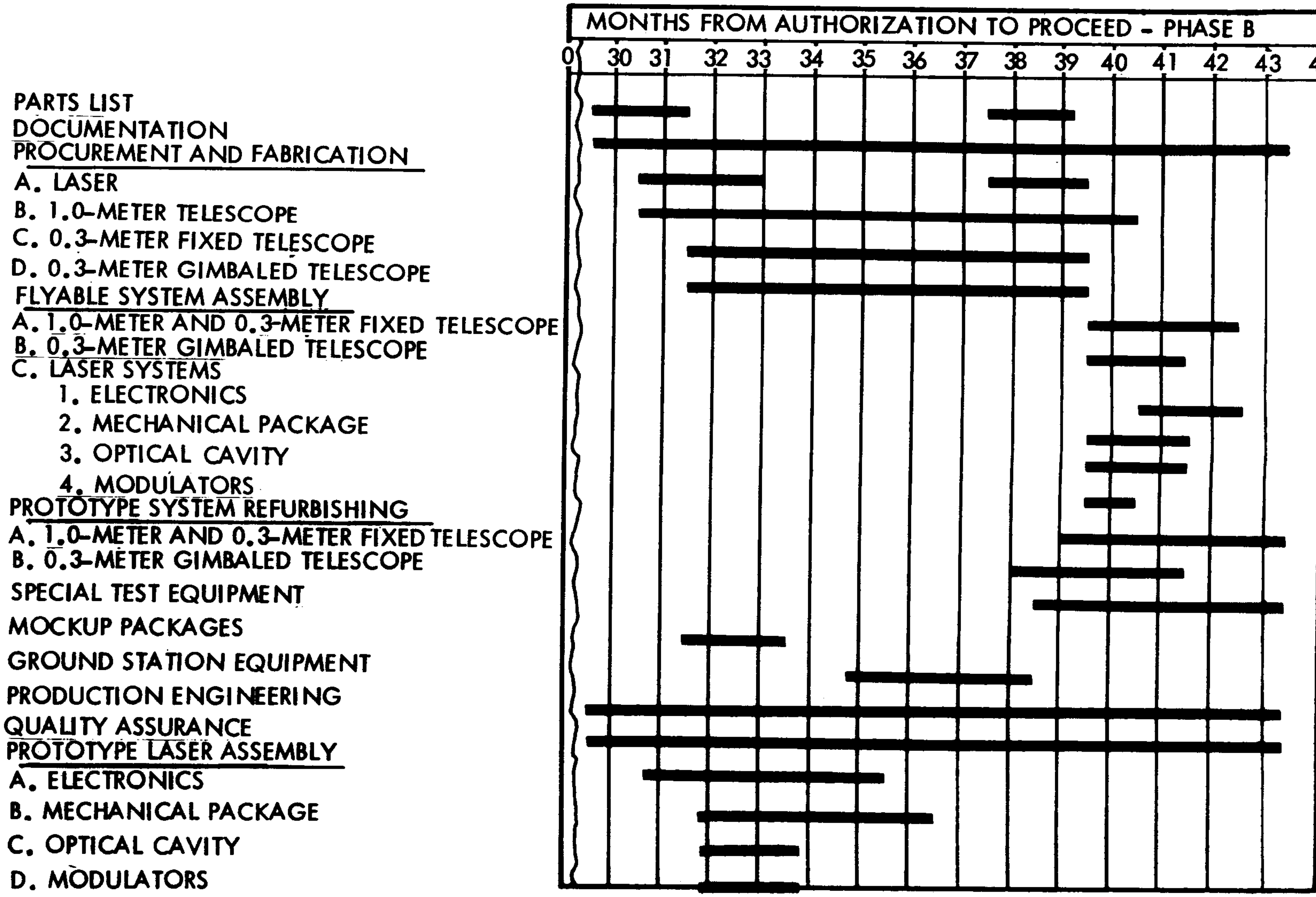

Figure 31.2.2.2.1-1. Laser Group Manufacturing Schedule

Plan, where applicable.

A special Product Engineering group will control the structural electronic assembly to ensure continuity of engineering design requirements through the production phase. All production items will receive Quality Assurance inspection to ensure adherence to hardware specifications and workmanship requirements.

The manufacturing effort will be fully integrated with the Preliminary Design, Development, Test, and Evaluation Plan; that is, manufacture of the flyable Laser Group experiment hardware will begin before completion of the prototype hardware, and run concurrently with the prototype assembly test and evaluation. Production of the laser systems, 3-meter and 8-meter receiver collectors will be performed by the Laser Contractor. The production of the 1-meter and 0.3-meter fixed telescope and the 0.3-meter gimbaled telescope will be performed by the Telescope Contractor.

31.2.2.2.2 Prototype System Refurbishment

After completion of the prototype hardware test, and shortly before the flyable experiment hardware assembly effort begins, the prototype hardware will be disassembled for detailed examination. Based on this examination, and the recommended design changes resulting from the prototype testing program, the system will be reworked to bring it up to flyable status for a backup system. There are no plans for routine fabrication of new components; only components which have demonstrated deteriorated performance or design safety margins, and those components where design changes have been made, will be reworked. The manufacturing schedule is laid out to provide refabrication effort to be concurrent with the flyable hardware assembly. This avoids personnel and facility conflicts, while providing the shortest feasible time span. After rework is completed, the modified prototype components will be reassembled, aligned, and made ready for acceptance testing. This activity occurs after the flyable hardware assembly is completed as shown in figure 31.2.2.2.1-1; in fact, it will be performed while the flyable hardware is being tested.

Three units of each laser, prototype, flight hardware will be produced, as well as one prototype unit of each telescope assembly. After preliminary checkout, the first laser unit will be supplied to the Telescope Contractor for systems operational checks. The second laser unit will be assigned to formal space qualification tests, and the third unit will be retained by the Laser Contractor for engineering tests and modifications. Four laser systems will be produced for a total of twelve laser units.

31.2.2.2.3 Implementation of Flyable System Design Documentation

The time spans shown in figure 31.2.2.2.1-1 provide additional design time to incorporate engineering changes derived from the prototype hardware assembly, test, and evaluation efforts. During the test and evaluation effort, required engineering changes will be implemented in the design drawings and the flyable hardware concurrently. The prototype drawings will be updated to reflect the necessary changes to be implemented during the prototype hardware refurbishment. Design draftsmen will work with the design engineers to assure an early release and prompt updating of all drawings.

31.2.2.2.4 Flyable System Assembly

The assembly of the flyable telescope and laser experiment hardware will be implemented as shown in figure 31.2.2.2.1-1. This assembly will be identical to the effort described in the Preliminary Design, Development, Test, and Evaluation Plan prototype hardware assembly plan. After assembly, the 1-meter and 0.3-meter fixed telescopes, the 0.3-meter gimbaled telescope, and all laser hardware will be functionally and environmentally tested, as described in the Test Plan.

31.2.2.2.5 Flyable System Fabrication and Production

This effort will begin during the latter portion of the prototype procurement and fabrication time span as denoted in figure 31.2.2.2.1-1. The major pacing items will be the 1-meter primary and other large mirrors, frames and pedestals for the 3-meter and 8-meter collectors, ground station interferometers, and mirror segments for large-aperture receivers.

One unit of the 1-meter and 0.3-meter fixed telescopes and the 0.3-meter gimbaled telescope, as well as two units each of four laser systems will be produced. One laser unit will serve as a backup system at the launch facility. The remaining laser unit will replace the prototype hardware prior to the final spacecraft integrated systems test. This will be done to ensure fresh laser tubes in orbital operation.

31.2.2.2.6 Special Test and Ground Station Equipment

Two consoles of special test equipment will be produced. The first unit will be used at the Telescope Contractor's facility to check out the laser system after telescope mating. The second test console will be used to check out the laser systems after mating the telescope with the spacecraft at the Prime Contractor's facility.

One prototype laser system and one production unit of four laser types will be produced. The prototype unit will serve as a spare unit at the optical tracking station. One 3-meter and one 8-meter collector will be produced for installation at the ground station. The 3-meter collector will serve as a prototype for the 8-meter collector.

31.2.2.2.7 Production Areas and Long Lead Item Procurement

The following production areas, located at the Laser Experiment Group's facility, are to be utilized in producing the required experiment hardware:

a. High Reliability Assembly Room

b. Thick-Film Miniaturization Facility

c. Metal Shops

d. Optical Assembly Room

All other manufacturing support equipment, (jigs, tooling, operations sheets), developed during the prototype hardware fabrication, will be used and will not require additional modification unless substantial engineering design changes are made.

Long lead items will be ordered as soon as mechanical and electrical interfaces are defined. Some of the long lead items to be purchased are:

a. Optical Lenses

b. Mirror Segments for Large Aperture Receivers

c. Ground Station Pedestals

d. Ground Station Interferometer

e. Power Supplies

f. Frames and Pedestals for the 3-meter and 8-meter collectors.

31.2.2.2.8 Cost and Scheduling

The manufacturing cost for the Laser Group of experiments is $4.82 million. The manufacturing effort for the Laser Group of experiments is to be completed in 43 months from Authorization to Proceed Phase B shown in figure 31.2.2.2.1-1.

31.2.2.3 Large Optics Group Manufacturing Plan

31.2.2.3.1 General

The fabrication of the flight hardware for the Large Optics Experiment Group are the main activities presented in this plan. In addition, this plan encompasses the refurbishment of the prototype equipment for use as a backup flight article. These activities are summarized in figure 31.2.2.3.1-1 and discussed herein with frequent reference to the Large Optics Experiment Group Preliminary Design, Development, Test, and Evaluation Plan.

The manufacturing and assembly efforts for the Large Optics experiment well structure, and all included subsystems except the primary mirrors, overlap each corresponding phase of the prototype effort. The manufacture of the primary mirrors follow the Preliminary Design, Development, Test, and Evaluation design effort directly. This concurrent effort on prototype and flyable systems is necessary to reduce expended time to a minimum.

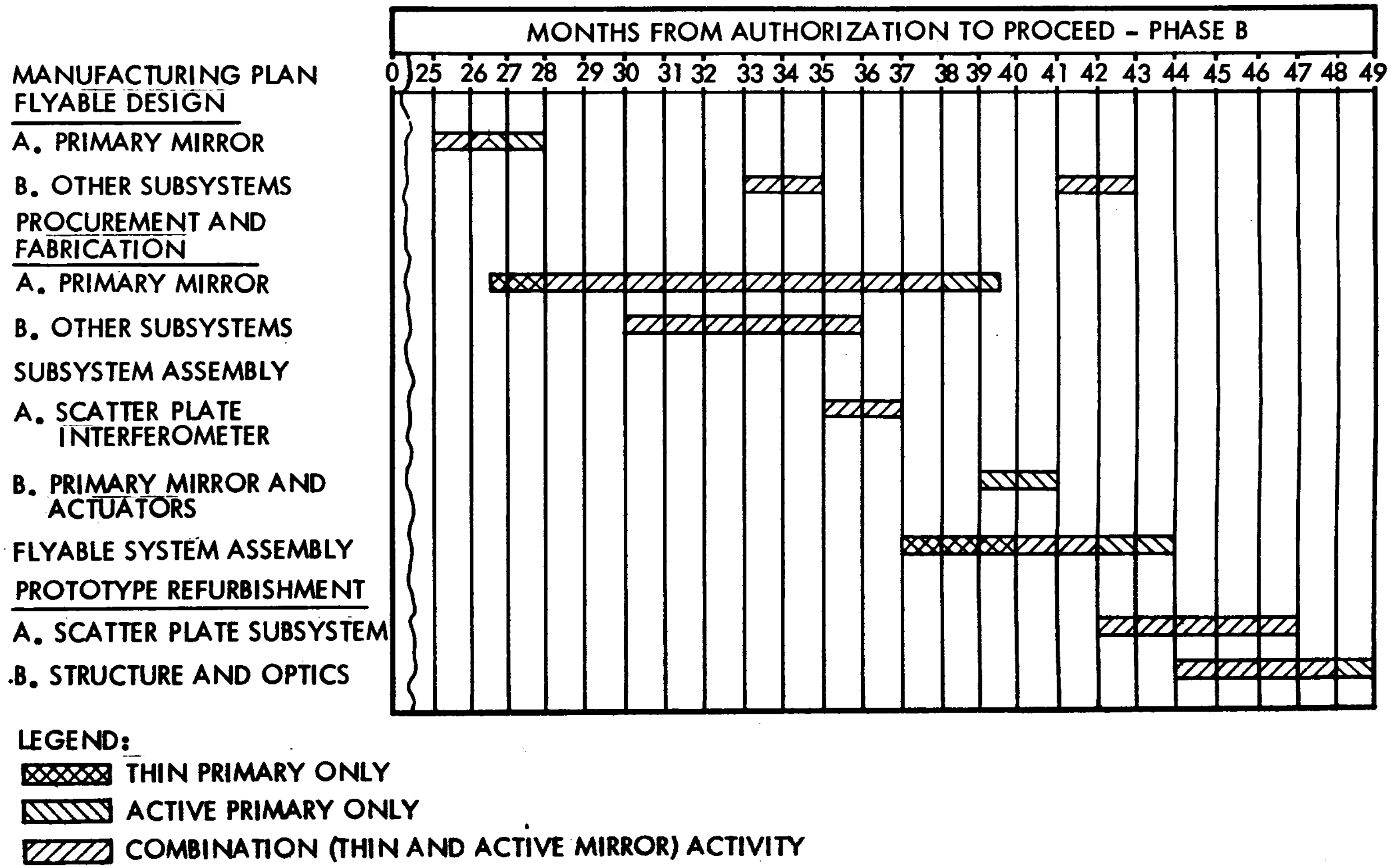

Figure 31.2.2.3.1-1. Large Optics Group Manufacturing Schedule

31.2.2.3.2 Implementation of Flyable Design Documentation

31.2.2.3.2.1 Primary Mirrors

Although this activity has considerable overlap with the mirror design effort depicted in the Preliminary Design, Development, Test, and Evaluation Plan, only one integrated design effort is really implied (because no primary mirror manufacturing is performed in the Preliminary Design, Development, Test and Evaluation Plan, as noted above). This plan encompasses changes in mirror design necessitated by the results of the primary mirror tests. No additional redesign period is anticipated for the primary mirrors, unlike the other subsystems.

31.2.2.3.2.2 Other Subsystems

Additional design time is provided to incorporate engineering changes in the telescope structure, secondary mirror, optical instrumentation, bladder, and thermal actuator subsystems. The first span will be responsive to the latest information from the prototype subsystem assembly and test effort, and the nearly completed system assembly phase. During the second span, engineering changes will be implemented where required (in the design drawings and the flyable hardware concurrently) as a result of the completed prototype testing program. This span also provides for updating the prototype design to reflect the necessary changes for system refurbishment.

31.2.2.3.3 Flyable System Procurement and Fabrication

31.2.2.3.3.1 Primary Mirrors and Nest

The primary mirror blanks will be fabricated at the Telescope Contractor's outside facilities; this effort will begin immediately after completion of the flyable design. The primary mirror fabrication encompasses manufacture of the mirror blanks; grinding and rough figuring; polishing, aluminizing, and final (magnesium fluoride) coating. Throughout these phases the primary mirror will undergo several thermal cycles for stress relief and optical tests to determine the figure. Most operations will be performed on the mirror nest, which, therefore, will be manufactured first. The methods used for mating mirror and nest initially, and after each removal, will be determined during the prerequisite technology phase.

The required manufacturing support (jigs, fixtures, tooling, etc.) will be supplied by the subcontractors. The results of the optical tests of the mirrors both during manufacturing activities and at completion, form a key part of the optical baseline data used for comparison later in system test, and in orbit; this is especially true for the thin primary mirror where accurate measurements may not be possible once the mirror is removed from the nest and before it is in orbit.

31.2.2.3.4 Subsystem Assembly

31.2.2.3.4.1 Scatter Plate Interferometer

The components within the scatter plate interferometer subsystem will be assembled and functionally checked while fabrication continues on the flyable mirrors. This activity is analogous to the corresponding prototype subsystem assembly effort. The Foucault tester and spacecraft autocollimator will be processed separately, but are included in all interferometer activities noted in this plan. After completion, this subsystem will be tested separately as shown in the Flyable Test Plan.

31.2.2.3.4.2 Active Primary Mirror and Actuators

Upon completion of the fabrication effort for the components of this subsystem (i.e., the actuators and heaters, the reference plate, and the active primary mirror), they will be integrated while assembly work is proceeding independently on the thin primary mirror in the experiment structure. This effort will be similar to that on the prototype, except that no preliminary assembly with a thin plate is anticipated. After integration, the mirror and actuator assembly will be thoroughly tested (as noted in the Flyable Test Plan); it will then be available for flyable system assembly.

31.2.2.3.5 Flyable System Assembly

This effort will begin with assembly into the experiment structure of the hatch, optical parts, and subsystem housings and mountings (while the thin mirror is completing fabrication, and the interferometer is being tested). Then, as they become available, the thin mirror, the bladder, the interferometer, and the active mirror and actuator assembly will be integrated. These activities are like those described in the corresponding Preliminary Design, Development, Test, and Evaluation Plan. Upon completion, the flyable assembly will be functionally and environmentally tested as noted in the test plan.

31.2.2.3.6 Prototype Refurbishment

31.2.2.3.6.1 Scatterplate Interferometer Subsystem

Immediately after completion of the prototype system test, the prototype interferometer will be removed for disassembly and inspection. Based on this inspection, and the results of prototype testing, the interferometer will be reworked to flyable status for use as a backup system; after rework this subsystem will be evaluated as noted in the test plan.

31.2.2.3.6.2 Structure and Optics

There is little manufacturing rework that can be done on the primary mirrors; in particular the thin primary will receive no more rework than a surface cleaning. Other components of the mirror experiments well will be disassembled and inspected for rework. This operation will be delayed until the flyable system assembly is complete (and possibly for the optical baseline portion of the flyable system test) if, as anticipated, disassembly and assembly are performed on the same optical bench. After rework, the experiment well will be reassembled, aligned, and readied for testing as the backup flight system (see the test plan).

31.2.2.3.7 Cost and Schedules

The manufacturing cost, including manpower and materials, for the Large Optics Group of experiments is $919 thousand. The manufacturing effort, for this group of experiments, is to be completed in 48 months from Authorization to Proceed - Phase B (figure 31.2.2.3.1-1).

31.2.2.4 Fine Guidance and Isolation Comparison Group Manufacturing Plan

31.2.2.4.1 General

This plan encompasses the fabrication and production of both the prototype and flight hardware associated with the Fine Guidance and Isolation Comparison Group of experiments. A summary of the manufacturing plan is presented in figure 31.2.2.4.1-1. Discussion of those activities presented will follow, referenced to pertinent aspects of the Preliminary Design, Development, Test, and Evaluation Plan, where applicable.

The flyable manufacturing effort (figure 31.2.2.4.1-1) overlaps the corresponding prototype phases to a large extent. The alternate approach, to have the flyable manufacturing effort follow completion of the prototype system test, was rejected in order to compress the schedule and allow for a minimum time span.

31.2.2.4.2 Implementation of Flyable Design Documentation

This effort will be initiated at the conclusion of the prototype fabrication and continue through the subsystem and system testing efforts of the Preliminary Design, Development, Test, and Evaluation Plan.

The time span depicted in figure 31.2.2.4.1-1 indicates early feedback of design information from the prototype fabrication effort into the flyable design fabrication. A more substantial period for design begins with the completion of prototype fabrication, and utilizes information not only from the subsystem and system assembly phases, but also from the first functional test, at the earliest possible time. It is anticipated that no additional flyable design time will be required after completion of the prototype system test. Design changes will be implemented into the drawings and into the flyable hardware concurrently. The final time span provides time for updating the prototype design, based on prototype testing, to reflect the necessary changes for system refurbishment.

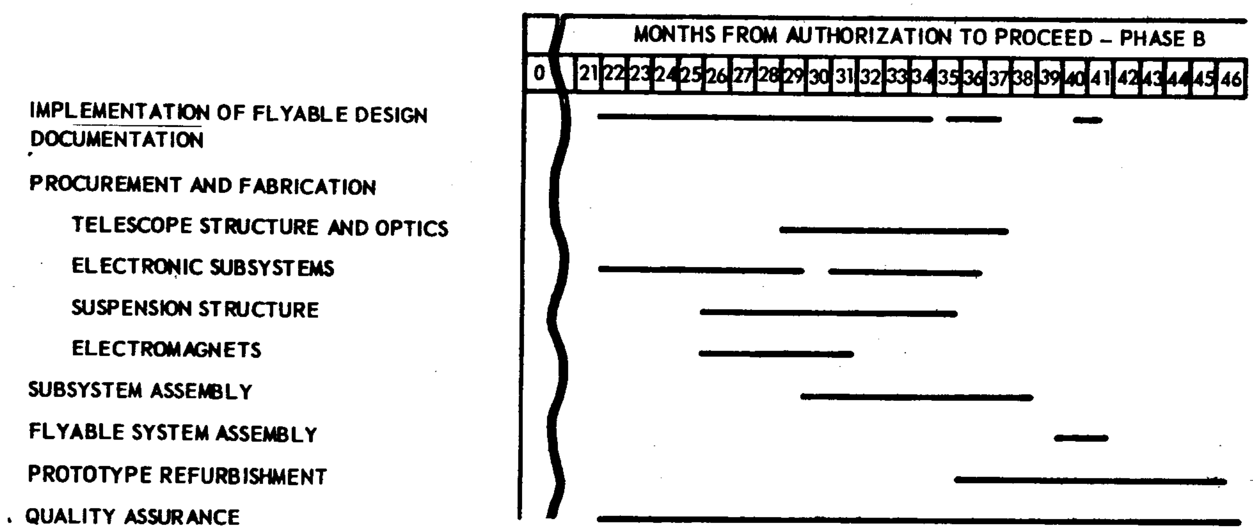

Figure 31.2.2.4.1-1. Fine Guidance and Isolation Comparison Group Manufacturing Schedule

31.2.2.4.3 Procurement and Fabrication

31.2.2.4.3.1 Telescope Structure and Optics

This equipment group consists of the primary and secondary mirrors, and the telescope structure; this is the pacing item in the Fine Guidance Experiment fabrication effort. The activities in this phase are identical to those of the corresponding prototype equipment (see the Preliminary Design, Development, Test and Evaluation Plan for the Fine Guidance and Isolation Comparison Group).

31.2.2.4.3.2 Electronic Subsystems

All remaining equipment of the Fine Guidance Telescope is included in this group; the major components are the coarse/intermediate subsystem, the fine pointing subsystem, and the protect circuits. The first two subsystems are both complex, and include several long-lead items. The detailed breakdown of the subsystems and the fabrication activities performed, as given in the Preliminary Design, Development, Test and Evaluation Plan, are accurate for the flyable systems, except that the time spans are reduced as shown, reflecting prototype experience.

Procurement of some of the electronic subsystems, such as the accelerometers, for the Comparison of Isolation Techniques Experiment can begin at the initiation of the design phase, based on information from the engineering prototype. Other electronic components, such as the servo electronics, must await completion of the detailed design, but will require less lead time.

31.2.2.4.3.3 Suspension System Structure

The structure includes the structural components of the individual suspension systems, the structure to hold these together, and the interface with the spacecraft. The fabrication of the structure will start at the time the first detailed design drawings are prepared and continue through the subsystem assembly phase.

31.2.2.4.3.4 Electromagnets

The procurement of the electromagnets will start at the completion of the first detailed drawings, and is estimated to require six months to complete. The fabrication of the electromagnets will be accomplished at selected vendors.

31.2.2.4.4 Subsystem Assembly

As each of the above subsystems is fabricated, it will be assembled in parallel but separate activities, while the remaining subsystem fabrication continues. Upon completion, each subsystem will be tested. This activity, together with the subsystem test, is analogous to the prototype activity previously discussed (see the Preliminary Design, Development, Test, and

Evaluation Plan).

31.2.2.4.5 Flyable System Assembly

Upon completion of testing, each subsystem will be integrated with the telescope structure, optics, and suspension system. Each subsystem, when integrated, will be aligned and checked optically and functionally for maximum performance in all operating modes, by monitoring the various outputs. Upon completion, the Fine Guidance and Isolation Comparison Group of experiments will be available for acceptance testing, and delivery for OTAES spacecraft integration.

31.2.2.4.6 Prototype Refurbishment

The prototype subsystems will be disassembled for inspection and refurbishment after completion of the prototype system test. The anticipated work on the optics will be limited to cleaning and realignment. Structural, electronic, and electromechanical parts will be reworked or replaced completely, if testing or inspection indicates any degradation in reliability or performance. Upon completion of rework, the backup system will be reassembled and aligned identically to the flyable system.

31.2.2.4.7 Cost and Scheduling

The manufacturing cost for the Fine Guidance and Isolation Comparison Group of experiments is estimated to be $1.82 million. The manufacturing effort for this group of experiments is to be completed in 46 months from Authorization to Proceed - Phase B (figure 31.2.2.4.1-1).

31.2.3 Preliminary Experiment Test Plans

31.2.3.1 Introduction

The Preliminary Design, Development, Test and Evaluation Plan presented those tests conducted on other than flight hardware to determine the feasibility of the design approach, the evaluation of experiment hardware performance, and the tests necessary to demonstrate that the hardware specifications have been complied with when the hardware is subjected to the intended environment. The testing presented in this plan encompasses the anticipated testing activities for both the flyable and the refurbished prototype experiment hardware to be used on the OTAES spacecraft. The activities presented here closely follow the activities of the Manufacturing Plan and are also referenced to the Preliminary Design, Development, Test, and Evaluation Plan where applicable.

The test plans, including both cost and scheduling, as presented herein are based upon the minimum testing requirements necessary to space-qualify all flyable and backup systems of the experiment groups. All testing is to be completed in 52 months at a total cost of $1.46 million. A detailed cost and scheduling breakdown may be found in the following individual experiment group plans.

31.2.3.2 Laser Group Test Plan

31.2.3.2.1 General

This plan encompasses the tests which are to be conducted on the flyable system and the refurbished prototype system. Included in this plan are the testing procedures expected for the prototype and flyable systems for the Laser Group of experiments. A qualification testing program was developed for the prototype system in the Preliminary Design, Development, Test, and Evaluation Plan which included complete functional baseline test, environmental tests at qualification levels, and post environmental functional tests. The equipment, as described previously, consists of the fully assembled 1-meter laser telescope, the attached 0.3-meter telescope, the 0.3-meter separately gimbaled telescope, flight laser systems, test consoles, ground station laser systems, and a large-aperture receiver. A Gantt Chart presentation of the activities for the Laser Group of experiments is shown in figure 31.2.3.2.1-1.

Three prototype-flight models for each of four laser systems will be designated as test models. One will be used for integrated testing with the telescope, one for engineering tests and modification, and the third for formal flight qualification tests. All other units tested will be deliverable.

31.2.3.2.2 Test Plans, Procedures, and Fixtures

Test plans, detailed test specifications, and procedures for the prototype system will be completed early in the flyable system fabrication phase. Preparation of the identical documentation required for the flyable system, will begin at the same time. Optical and electrical test specifications and procedures will be identical; environmental test procedures will follow

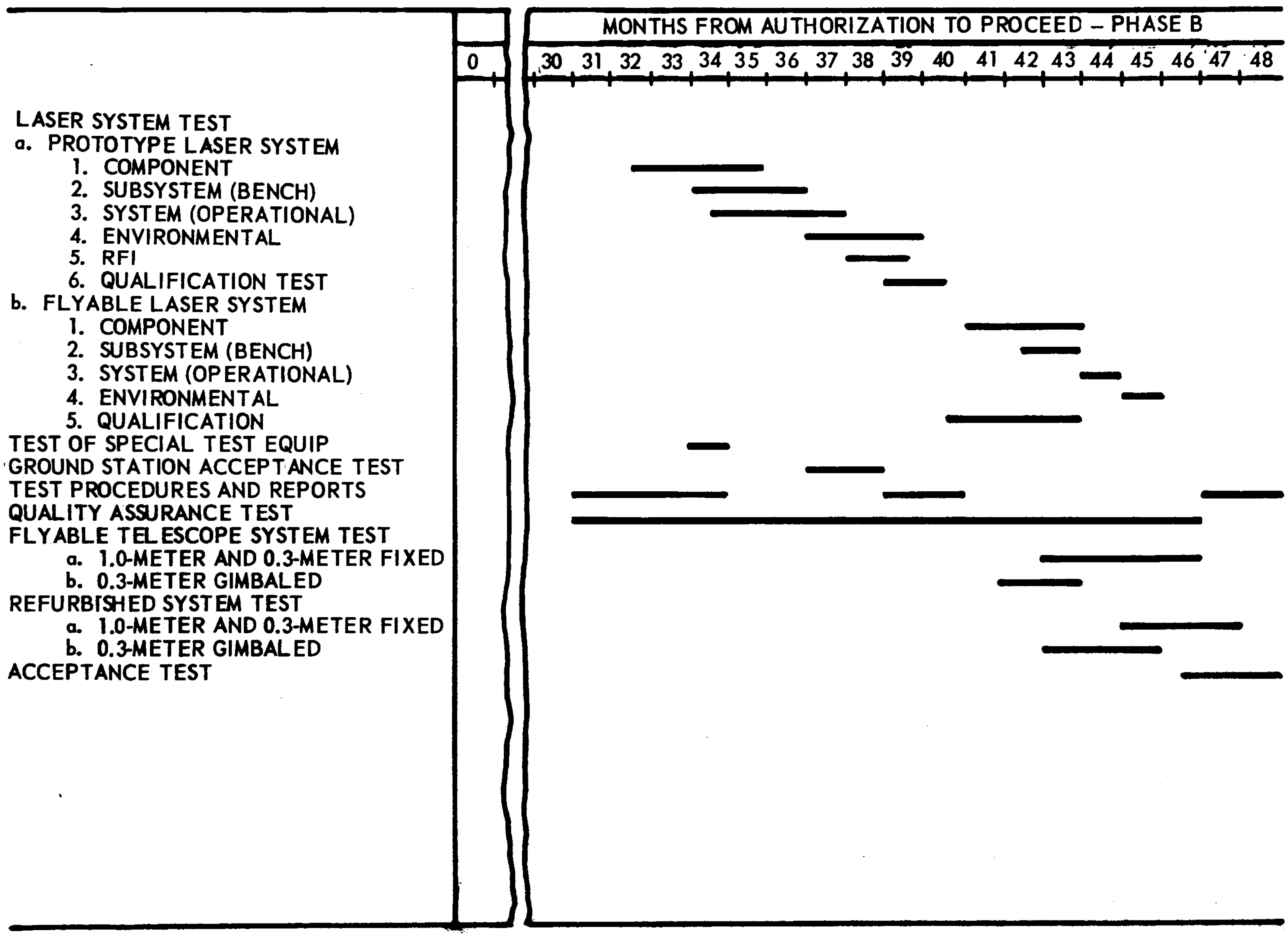

Figure 31.2.3.2.1-1. Laser Group Test Schedule

the same methods, but test levels in general will be lower. Also, flyable system testing will not include all the prototype test environments. The test equipment, fixtures, and simulators designed, fabricated, and procured for the prototype system test will be used; if necessary, after prototype testing, modifications will be implemented to incorporate improvements and allow proper testing of new design features in the flyable system.

31.2.3.2.3 Flyable System Tests for 1-Meter, 0.3-Meter Attached, and 0.3-Meter Gimbaled Telescopes

The test plan for these telescopes will have three main phases:

a. Complete Baseline Test

b. Environmental Test

c. Final System Functional Test

The baseline test will be the first phase of the testing time span; environmental and functional tests are also included in the same time spans. The baseline and final functional testing will be identical to that performed for the prototype system. For environmental tests, only temperature, vacuum, and vibration exposures are planned. For the temperature and vacuum exposures, conditions will be made comparable to orbital conditions, and functional tests performed within the limitations of the facility and setup. Vibration testing will be performed with all subsystems in prelaunch conditions, and in a non-operating mode; inputs will be applied in 3 axes, simulating launch levels. Upon completion of the final functional testing, the flyable system will be ready for integration into the OTAES spacecraft.

Equipment requirements include the following:

a. Temperature, vacuum, and humidity cycling

b. Screen rooms and monitoring equipment to measure operating RFI

c. Test consoles for the laser/electronic systems to control operation, test sequencing, provide power and video signals, and monitor and record system status.

d. Shock isolation tables to prevent test errors caused by ambient vibration.

e. Alignment benches to be used during alignment of optical lenses.

f. Other subsystem tests can be performed with standard test equipment (i.e., oscilloscopes, VTVM's, and signal generators).

31.2.3.2.4 Flyable Backup System Tests

After refurbishment in accordance with the activation described in the manufacturing plan, the original prototype system will be the backup system for the flyable system. This system will be tested identically to the flyable; its availability for testing will occur while the flyable is undergoing environmental exposures. This will permit baseline testing of the backup telescopes on the same setup used for the flyable; the backup system will complete its baseline testing, and move into environmental testing when the flyable is ready for final functional tests. This permits parallel testing efforts for each telescope (with only one setup), resulting in a substantial savings in time. On completion of the final functional tests, the backup 1-meter and 0.3-meter attached telescopes, and the 0.3-meter gimbaled telescope will be available for integration into the backup OTAES spacecraft.

31.2.3.2.5 Ground Station Testing

Testing of the 3-meter aperture will be done at the Laser Contractor's laboratory. Testing of the 8-meter aperture will be made at the ground station, where it will be assembled. Integration of the 8-meter equipment with the other equipment at the ground station will be accomplished.

31.2.3.2.6 Test Sequencing

Incoming inspection will test all components in which the vendor does not meet space qualification requirements. After production, subassembly tests will be performed on all units in accordance with procedures. Failure to meet procedure requirements will necessitate rework and retest until any malfunction is corrected.

Engineering tests will be performed on completed systems to verify proper operation. Alignment and calibration will be performed during the same time period. The responsible engineer will evaluate the test results before acceptance tests are performed. These test results will be compared to the acceptance test results to assure consistent equipment operation. During acceptance tests, the equipment will be calibrated, and the results will be recorded for flight reference.

31.2.3.2.7 Test Analysis and Reports

After the testing is completed, inputs and results will be presented in reports. The results will be checked against established criteria and modifications, or changes will be suggested for the items tested. Methods for connecting the prototype system to the flight article will be determined from the test results.

31.2.3.2.8 Cost and Scheduling

The total estimated cost for the testing of the Laser Group is $897 thousand. The time span for a complete testing program, together with the required results, is expected to be 48 months from Authorization to Proceed-Phase B as shown in figure 31.2.3.2.1-1.

31.2.3.3 Large Optics Group Test Plan

31.2.3.3.1 General

This plan encompasses the testing activity anticipated for the flyable and refurbished prototype of the OTAES Large Optics experiment system. These activities follow the activities of the Manufacturing Plan in sequence, and are also referenced to the Large Optics Preliminary Design, Development, Test, and Evaluation Plan, which details the qualification program. A Gantt Chart presentation of the testing activities for the Large Optics Group is shown in figure 31.2.3.3.1-1.

31.2.3.3.2 Test Plans, Procedures and Fixtures

Test plans, detailed test specifications, and procedures for the prototype system will be completed shortly before completion of the flyable, thin, primary mirror fabrication phase. Preparation of the required documentation for the flyable system will begin at this time, as shown in figure 31.2.3.3.1-1. Optical and electrical test specifications and procedures will be identical; environmental test procedures will follow the same methods, but test levels, in general, will be lower. Also, flyable system testing will not include all the prototype test environments. The test equipment, fixtures, and simulators designed, fabricated, and procured for the prototype system test will be used; if necessary, modifications will be implemented (after prototype testing) to incorporate improvements and allow proper testing of new design features in the flyable system. The necessary test facilities required are discussed in the Facilities Plan.

31.2.3.3.3 Flyable Subsystem Tests

31.2.3.3.3.1 Scatter-Plate Interferometer

After assembly, this subsystem will receive a complete functional test, as described for the prototype subsystem; all activities noted for this subsystem will also be performed simultaneously, but separately, on the Foucault Test and Autocollimator. For environmental test, temperature, vacuum, and vibration exposures are planned. These exposures are also planned for the prototype interferometer, but at lower test levels. Temperature and vacuum exposures will be in an operating mode, with conditions simulating orbital parameters. Vibration testing will be performed in three axes, with the subsystem in a non-operating mode, and with mountings and input levels simulating actual launch conditions. The time frame depicted in figure 31.2.3.3.1-1 is sufficient to allow for all planned testing, but the timing for this test is flexible; it need only be available for the flyable system test, discussed below, which begins significantly later. At the completion of system test, the interferometer will be prepared to ship for flight integration.

31.2.3.3.3.2 Active Primary Mirror and Actuator Control Subsystem

The flyable, active, primary mirror and actuator control subsystem will proceed from an independent assembly effort to a subsystem testing effort; during this time, the remainder of the flyable system will continue in a parallel assembly effort, resulting in a large time span reduction. Although accurate optical measurements may not be possible until this subassembly is mounted into the experiment well structure, it is tentatively planned that vacuum

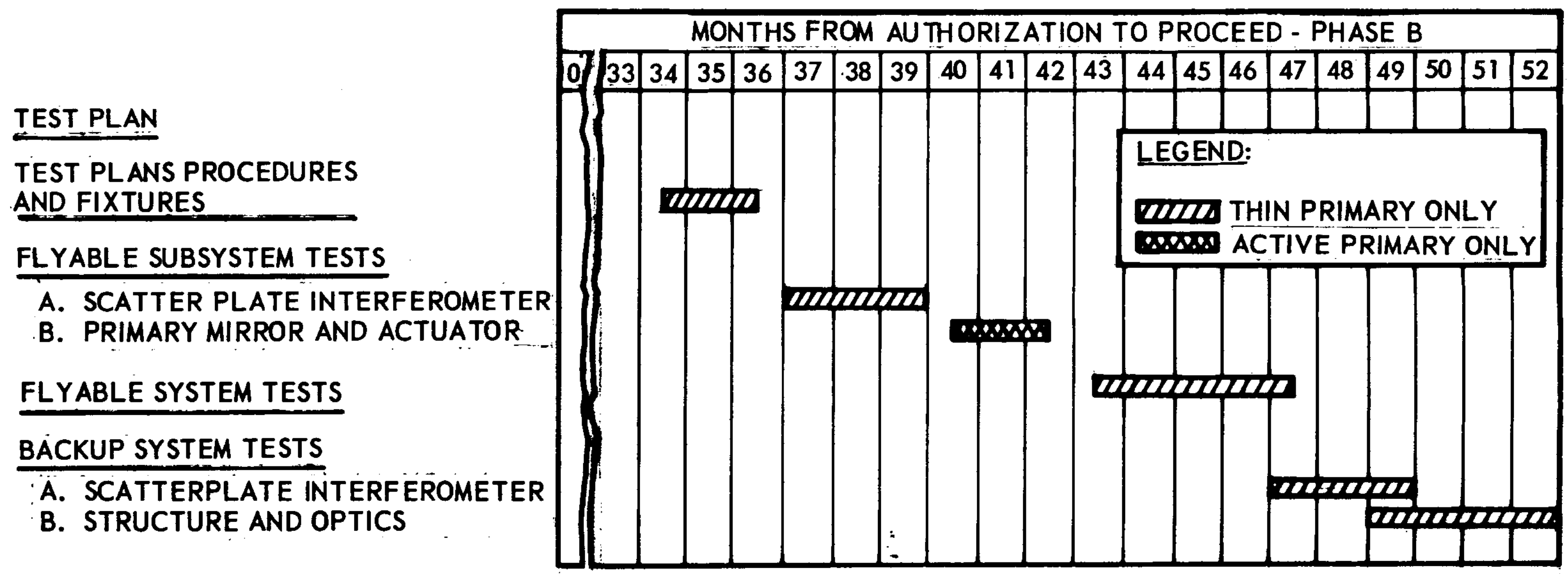

Figure 31.2.3.3.1-1. Large Optics Group Test Schedule

testing can be completed on the subassembly before integration. In addition, thermal testing will be performed on the subsystem, reducing the time span needed for full evaluation of the active mirror during the subsequent flyable system temperature test. After subsystem testing, this component will be available for integration with the flyable system assembly.

31.2.3.3.4 Flyable System Tests

After integration of all components and subsystems in the flyable assembly, Acceptance Test will begin; this consists of the following three phases:

a. Complete Baseline Functional Tests

b. Environmental Tests

c. Final System Functional Tests

The time span denoted in the Gantt Chart covers all three of these tests, performed in the above sequence. The baseline and final functional tests are identical to those described in the Preliminary Design, Development, Test, and Evaluation Plan for the prototype system; the environmental tests will consist of temperature and vibration exposures only. The tests will be similar to the test performed on the prototype system, as described in the Preliminary Design, Development, Test, and Evaluation Plan, but input levels, simulating launch and orbital conditions, in general, will be lower. On completion of the final functional testing, the primary mirror experiments systems will be prepared to ship for flight integration.

31.2.3.3.5 Flyable Backup System Tests

31.2.3.3.5.1 Scatter-Plate Interferometer Subsystem

After refurbishment of the prototype subsystem, it will be subjected to functional and environmental tests identical to those for the first flyable system. This activity will be coordinated with backup system testing, because the interferometer is required for the complete optical tests.

31.2.3.3.5.2 Structure and Optics

This group consists of the complete mirror experiment system, except for the stowable optical instruments. Its testing will be delayed until the completion of the flyable system tests, when the optical bench will become available. The testing will be identical to the functional and environmental tests specified for the first flyable system. After completion of the testing, the backup flyable system, including stowable optical instruments, will be prepared for shipment.

31.2.3.3.6 Cost and Schedules

The testing cost of the Large Optics Group of experiments is estimated to be

$86 thousand, and is to be completed in 52 months from Authorization to Proceed-Phase B, as shown in figure 31.2.3.3.1-1.

31.2.3.4 Fine Guidance and Isolation Comparison Group Test Plan

31.2.3.4.1 General

This plan encompasses the testing activities anticipated for the flyable and refurbished prototypes of the OTAES Fine Guidance and Isolation Comparison Experiment Group. The activities presented here closely follow the activities of the manufacturing plan, and are also referenced to the Preliminary Design, Development, Test, and Evaluation Plan, which details the qualification testing program. An outline of the testing activities is depicted in figure 31.2.3.4.1-1.

31.2.3.4.2.1 Flyable Subsystems

This effort is an extension of the corresponding prototype system phase; preparation of test plans, procedures, and specifications for the flyable subsystem will follow directly from the prototype documents. While the optical and electrical test will not change, the environmental procedures for the flyable hardware, in general, will have lower test levels, and will not include all prototype environments. The prototype test equipment fixtures and simulators will be used for the flyable system, modified if necessary to incorporate design changes.

31.2.3.4.2.2 Flyable Systems

This effort follows immediately from the corresponding prototype phase; however, there is considerable flexibility in the scheduling of this phase. These procedures also will be applicable to the flyable systems test performed on the air bearing table; in addition to the required documentation, any special adapters, fixtures, simulators, or test instruments necessary for the air bearing table test will be completed in this effort.

31.2.3.4.3 Flyable Subsystem Tests

After subsystem assembly is completed, each subsystem that can be described by an input-output function will undergo functional, vibration, and thermal-vacuum tests. After completion of testing, the subsystems will be returned for integration with the flyable telescope or the suspension system test fixture.

31.2.3.4.4 Flyable System Tests

The flyable system, immediately after assembly is completed, will undergo a complete acceptance test phase. These tests will include baseline functional tests, temperature tests, vacuum tests, and vibration tests which will be similar to those described for the prototype system. The final system functional test will include complete measurement of the system performance with simulated inputs, while they are mounted on the air bearing

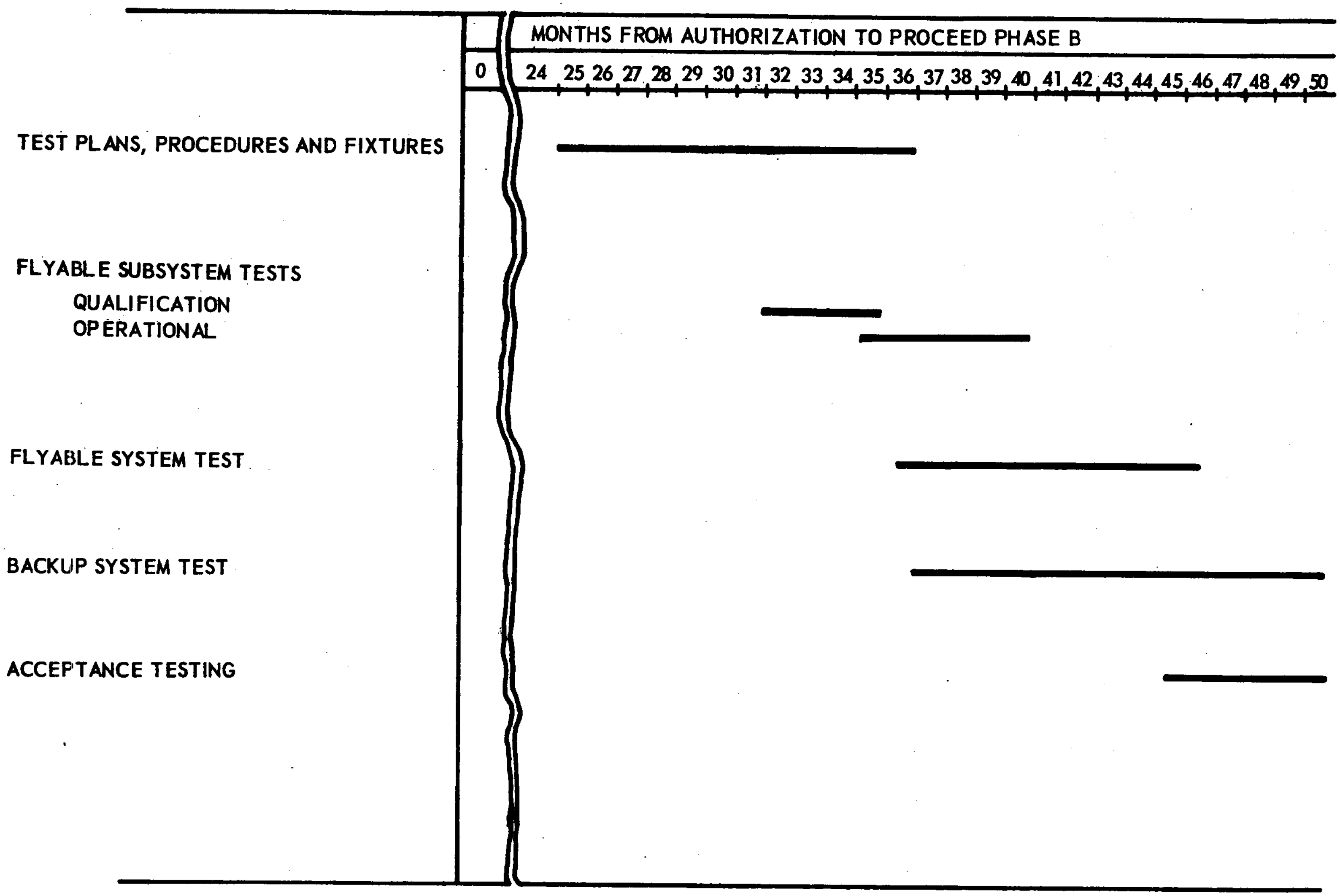

Figure 31.2.3.4.1-1. Fine Guidance and Isolation Comparison Group Test Schedule

table or suspension system test fixture. On completion of the flyable system tests, the hardware will be prepared for integration with the OTAES spacecraft.

31.2.3.4.5 Flyable Backup System Tests

The refurbished and reassembled prototype systems will be ready for test shortly after the completion of the above tests of the flyable systems; the backup systems will receive testing identical to that for the prototype.

31.2.3.4.6 Cost and Scheduling

The cost of testing the Fine Guidance and Isolation Comparison Group of experiments is estimated to be $478 thousand, and is to be completed in 50 months from Authorization to Proceed-Phase B, as shown in figure 31.2.3.4.1-1.

31.2.4 Preliminary Experiment Facility Plans

31.2.4.1 Introduction

This subsection summarizes the requirements necessary for support of the 13 hardcore experiments comprising the experiment program to be used on the OTAES spacecraft. The facilities required for manufacturing, test and checkout, and ground support of the experiments are discussed.

In many instances the same facilities may be utilized for each of the experiment groups (Laser, Large Optics, and Fine Guidance and Isolation Comparison). Many of the required facilities are currently available and can be used with only a small degree of modification. Other facilities will have to be constructed, as they are not now available. More detailed descriptions of the required facilities are given under the facility plans of the individual experiment groups.

The additional facilities and modifications to existing facilities is estimated to cost $12.267 million. The facilities will be required at various times from Authorization to Proceed - Phase B. Refer to the individual experiment groups for a detailed breakdown of cost and schedules.

31.2.4.2 Laser Group Facility Plan

The facility requirements for the Laser Group of experiments required for design, development, manufacture, and test prior to delivery to the launch facility are discussed in this plan. The facility requirements of the Laser and Telescope Contractors are discussed, followed by a description of the Optical Technology Test and Operations Station (OTTOS), required to support the Laser Group of experiments.

31.2.4.2.1 Laser Contractor Facility Requirements

31.2.4.2.1.1 Existing Facilities

Present facilities at the Laser Contractor's laboratories will support the experiment hardware through space qualification of lasers and associated electronics. The existing facilities and capabilities are:

a. Fabrication of laser tubes.

b. Adequate machine shops.

c. Cleanrooms for the assembly of high reliability electronics.

d. Production facilities for high reliability miniaturized electronics using thick film techniques.

e. Electronic development and test area.

f. Shock, vibration, radio frequency interference, temperature, humidity, and vacuum testing (except vacuum test at Orbital altitudes, which will be subcontracted).

g. Outdoor range for tests of laser transmitters and receivers.

h. Computer facilities.

31.2.4.2.1.2 Additional Facility Requirements

Expanded development and test activities due to the complexity of the OTAES program will require the addition of 1600 square feet to the optical systems laboratory at the Laser Contractor's facility. Long-range planning should allow the use of existing building space with modifications to the building, including the addition of partitions, work benches, storage cabinets, and water and electrical outlets. Because of high reliability requirements and the critical nature of the test, air conditioning will be required.

Additional equipment will be required to provide long-term tests during development and production of highly reliable laser equipment. (This is in addition to the Environment/RFI laboratories which will be used for normal and extended range tests.) This equipment includes:

a. Temperature chamber, measuring 1 by 0.5 by 0.5 meters, to provide hot and cold cycling.

b. Environmental chamber, measuring 1.5 by 1 by 0.5 meters, to provide hot and cold cycling, humidity, and vacuum conditions. This chamber will require the addition of an optical window for transmitting an undistorted laser beam during temperature cycling.

c. A minimum of one special two-bay console for exciting, controlling, and monitoring the laser system during test.

d. Two optical benches, 2 meters long, to be used for laser alignment.

e. Two special shock isolation tables.

31.2.4.2.1.3 Facility Requirements at Associate Contractors' Plants

Four hundred square feet of test and storage area will be required within the Telescope and Prime Contractors' facilities. One facility will be used for hardware maintenance, testing and alignment of the lasers during integration with the telescope. The second facility will be used for maintenance and testing the lasers during integration of the telescope with the OTAES spacecraft.

The Telescope and Prime Contractors are expected to provide space, work benches, storage cabinets, air conditioning, and all necessary electrical power outlets. Test equipment at each facility, including a two-bay test console for control, excitation, and monitoring of the laser system, will be provided by the Laser Contractor. A shock isolation table will be assembled at both associate contractors' facilities.

31.2.4.2.2 Telescope Contractor Facility Requirements

The special facility requirements, for the 1-meter and two 0.3-meter telescopes, required by the telescope contractor to fabricate, test, and produce the telescope hardware are discussed in this subsection. The Telescope Contractor's auxiliary optics and telescopes for the ground station are included.

31.2.4.2.2.1 Fabrication and Manufacturing

The fabrication of the primary and secondary mirrors (i.e., manufacture of the mirror blanks, machining, figuring, polishing, and coating with kanigen, aluminum, and magnesium fluoride as noted in the Preliminary Design, Development, Test, and Evaluation Plan) will be performed at existing facilities of selected vendors. Fabrication of the balance of optical components, such as flip mirrors, filters, beamsplitters, and pupil matching telescopes, will be performed at the facilities of the Telescope Contractor and its vendors, utilizing present facilities. The remaining components of the telescopes will be predominately standard structural, electronic, and electro-mechanical parts. These standard parts and all additional state-of-the-art parts required will also be within existing manufacturing capabilities.

31.2.4.2.2.2 System Assembly Requirements

The facilities necessary for component level assembly of the auxiliary optical, structural electronic, and electro-mechanical parts are presently available at the Telescope Contractor's facility. These include standard assembly, inspection, and test facilities in areas with controlled temperature, humidity, and dust particle count. For the assembly and alignment of the primary and secondary mirrors into the telescope's structure, a large stable platform with provisions for autocollemation and other optical sighting of the telescope will be required. This facility will require fixtures for handling and mounting structures up to 1-meter in diameter, and should be in a controlled environment. A 12.19-meter optical bench presently available at the Telescope Contractor's facility can be utilized. With a small degree of modification (the addition of a holding fixture and two displaced pyramid prism reflectors), the optical bench could handle the integration and boresighting of the 1-meter and the fixed 0.3-meter telescope. The mounting and final alignment of the other internal optical elements, transmitters, receivers, and trackers within the telescope will be performed on the same optical bench. For the 1-meter and 0.3-meter gimbaled telescope, the 6,328 angstrom (Å) laser transmitter can be aligned by sighting on its output beam. The 6,328 Å receiver and 4,880 Å tracker can be aligned by reflecting the beam back externally with a test flat. The alignment of the 0.3-meter fixed telescope's 10.6 μ transmitter and receiver may require externally mounted test sources and detectors which will be built and mounted in conjunction with the Laser Contractor engineering staff.

31.2.4.2.2.3 System Testing Requirements

As denoted in the Preliminary Design, Development, Test, and Evaluation Plan and in the Test Plan, the planned system testing consists of baseline functional tests and environmental tests. Functional tests will be performed on the optical bench previously discussed. Facilities are presently available for the planned dynamic tests (vibration, acceleration and shock). Facilities for temperature tests are also available at the Telescope Contractor's plant, but functional testing in these chambers during thermal exposure would be extremely limited. Facilities at Goddard Space Flight Center are designed to handle packages similar to the laser telescopes, and should enable more complete optical tests under temperature and vacuum test conditions. Consequently, no new environmental test facilities are required.

31.2.4.2.3 Optical Technology Test and Operations Station

The Laser Group of experiments will require an operational Optical Technology Test and Operations Station (OTTOS) to fully support the experiments. An astronomical observatory is often concerned with the quality of its best observing conditions. The occasional outstanding result among many observations may justify months of observing. OTTOS, on the other hand, is concerned more with the opposite end of the performance scale, poor observing conditions or total functional failure.

31.2.4.2.3.1 Site Requirements

Since experiments with spacecraft are so costly, high probability of being able to conduct the experiments once the spacecraft is launched is more important than the excellence of vision. Therefore, it is desirable to have a site for which: 1) sensors of significant downtime due to weather are predictable; and 2) during other seasons, the probability of unpredicted downtime is low and, particularly, the probability of an extended run of downtime is small.

Certain regions are incompatible with the OTAES requirements. These are zones subject to commercial air traffic, zones with high likelihood of jet contrail interference, and zones subject to dense air pollution from urban centers. The objection to aircraft in flight is not only possible interference with experimental procedure caused by temporary interruption of the telescopic line-of-sight, but also the possible danger of eye injury to airborne passengers and crew. The exclusion of airways excludes a large fraction of the total land area, especially around the larger coastal cities where air lanes converge near urban centers. Potential sites are isolated mountains with wooded surroundings, within reasonable distance of an established road or trail, meeting the following criteria:

a. Cloud - Not more than 30 per cent.

b. Fog - Not more than 5 days per year.

c. Sunshine - Not less than 70 per cent of available sunshine.

d. Solar Irradiation - Not less than 500 langleys per day.

e. Soluble Particle Matter - Not more than 5 micrograms per cubic meter.

f. Relative Humidity - Not greater than 70 per cent.

g. Wind Velocity - Not greater than 30 mph 99 per cent of time. Average wind not greater than 10 mph.

h. Airways - 70 miles from airlane centerline.

i. Altitude - Not less than 6,000 feet above mean sea level.

j. Seismic Limitations - Not greater than Class I (Modified Mercalli Intensity Scale of 1931 or Rossi-Forel Scale). Low incidence.

A rock stratum is desirable for foundation support. The mechanics of providing an adequate foundation dictate that the ground must have adequate bearing capacity, without the slipping or creeping which would be encountered with clay or silt. This is further emphasized by a finding of the Bureau of Mines that solid unbroken rock strata reduce earth wave amplitude through normal ground. Earth wave amplitudes through sandy soil may be three times greater than those through normal ground.

Existing continental U. S. optical facilities violate at least one of the above site selection criteria. In general, those which satisfy the location requirements do not meet the seismic or meteorological requirements. Sites which may satisfy all of the criteria are:

a. Atascosa Peak, Arizona

b. Captain Mountains, New Mexico

c. Chiricahua Peak, Arizona

d. Chisos Mountains, Texas

e. Guadelupe Mountain Range, New Mexico

f. Kingston Peak, California

g. Mount Wrightson, Arizona

h. Sacramento Mountains, New Mexico

i. White Mountains, California

The OTAES program plan is based on the assumption that the site selection and initial preparation (access, power, geodetic survey, etc.) for an OTTOS will be underway 1968. Any delay in OTTOS availability beyond 1970 will cause a delay in OTAES. If an OTTOS is not established, the Laser Group of experiments, as presently conceived, cannot be conducted.

31.2.4.2.3.2 Equipment Requirements

The special equipment necessary to support the Laser Group of experiments is:

a. A seismically and meteorologically isolated mount for a diffraction-limited optical receiving aperture. This tracking telescope, of nominal 1-meter aperture, will have all-reflective optics and a fine pointing capability of ± 5 microiadians.

b. Data links to the Deep Space Instrumentation Facility and the Manned Space Flight Network having a 51,200 bits/per second capacity.

c. Backup commercial video link (5MHz) to the nearest LE-350 computer site.

d. Experiment control consoles adequate for handoff control during critical experiment periods.

e. Meteorological ground station augmented for rawinsonde/radiosonde operations distributed up to 150 miles south of the ground station.

f. A mount for precision pointing of a coherent optical ground beacon.

g. A 0.1-meter transmitting telescope, having suitable beam combining optics behind the mirror for a single-frequency, 6,328 Å laser transmitter.

h. A seismically isolated tracking mount to support an 8-meter segmented optical aperture.

i. A similar tracking mount suitable for a 3-meter optical aperture.

j. A 1-meter transmitting telescope with a 4,880 Å laser capable of approximately 1 KW average power output. A heterodyne receiver consisting of an array of 16 telescopes, each about 12.7 cm in diameter. Capability is also to be provided for an alternate direct, photon bucket, receiver of aperture in the order of 2 meters.

k. An additional gimbaled transmitter-receiver approximately 4 miles from the base station. The two locations will be surveyed to provide extremely accurate data on their relative and geodetic positions.

l. Seismically and meteorologically isolated mounts for optical interferometer receiving operations, which may be separated by a distance as great as 10 meters.

m. Two folded optical telescopes evacuated with apertures of 2 cm, capable of focusing their outputs on a common photomultiplier. Provision must be made to insert filters, attenuators, or modulators in the optical path of either telescope. Since separations of up to 10 meters are planned, fixed installations are required. Phase-compensated paths will be needed. These could be provided with a ground-based auxiliary laser.

31.2.4.2.3.3 OTTOS Support Facilities

An OTTOS auxiliary site is required for point ahead and transfer tracking experiments. This site should be located within 4 miles of the primary OTTOS facility and must meet the same site selection criteria used for the primary facility.

The meteorological information subsystem of the OTAES data-management system is composed of 15 balloon-release stations, 4 radio theodolite stations, and one tropospheric scatter station. This network supports the entire OTAES program. Details are provided in Sylvania Electronics Systems OTAES Data Management Study of May 1967.

31.2.4.2.3.3 Costs

The facility costs in this subsection are preliminary estimates, which will be redefined during Phase B. OTTOS facility costs are dependent to a great extent on the final site selection; the more remote or inaccessible the site is, the greater the actual facility costs will be. The following figures are considered to be representative:

a. OTTOS Facility -(Includes site, building, antenna mounts, water, power, access road, and helo pad), $3,635,000.

b. Auxiliary Site -(Includes building, antenna pedestal, power, and helo pad), $206,000.

c. Remote Troscatter Station -(Building, antenna, power, and helo pad), $219,000.

d. Remote Radio Theodolite Stations, $442,000.

e. Video Microwave Links (OTTOS to DSIF Goldstone), $270,000.

f. Telephones and Communications Links, $80,000.

Furniture, Architectural Services, and Engineering, $280,000.

The total cost of these facilities is $5,132,000.

OTTOS supporting equipment estimates, with Government-Furnished Equipment (GFE) assumptions identified, are summarized below:

a. Materials, tools, and test equipment, $173,000.

b. Purchase clock, weather and seismograph instruments, $30,000.

c. Purchase data modems, $15,000.

d. Purchase TTY, FAX, and Telephones 1259 Adaptor, $30,000.

e. Purchase TM AUSB Modulator/Demodulator, $15,000.

f. Purchase display and projection system, $600,000.

g. Purchase 642B Computer, GFE.

h. Purchase buffer, GFE.

i. Purchase land-line communication, GFE.

j. Fabricate and assemble power subsystem, $90,000.

k. Fabricate and assemble performance monitor and fault locator, $90,000.

l. Fabricate and assemble communications network, $150,000.

m. Pack, deliver, install, integrate, check out, and test, $1,830,000.

n. Interferometer, $700,000.

o. 3-meter direct detection antenna, $400,000.

p. 8-meter direct detection antenna, $1,450,000.

q. Special test equipment, $75,000.

r. 1,600-square foot facility at Laser Contractor site and two 400-square foot facilities at associate Contractors, $50,000.

The total cost of these support facilities is $5,573,000.

The total cost of the OTTOS and support facilities is $11,955,000.

31.2.4.2.3.4 Schedules

The complete OTTOS facility schedule, including the auxiliary site, remote troposcatter station, and radio theodolite stations, is shown below:

a. Site selection, January 1968.

b. Limited testing (grading and survey but no permanent structures), June 1968.

c. Heavy instrument mounts and control center, January 1969.

d. Integrated site operation, June 1969.

e. Airborne testing, January 1970.

f. LCSE testing, June 1970.

g. OTAES launch, April 1972.

h. Laser Contractor facility (1,600 square feet), 11 months after ATP Phase B (September 1968).

i. Special test equipment: First set, September 1968; second set, September 1969; third set, September 1970.

j. Telescope Contractor facility (400 square feet), July 1969.

k. Integration Contractor facility (400 square feet), December 1969.

31.2.4.3 Large Optics Group Facilities Plan

31.2.4.3.1 General

This plan encompasses special facilities requirements for the thin primary mirror and active primary mirror equipment. The manufacturing phase is discussed in this subsection. The thin and active primary mirrors will be fabricated by several selected vendors. Facilities required will be supplied by the vendors. Although some vendors considered are not currently capable of handling this size mirror, the required tables may be readily rented. The remainder of the experiment well equipment (i.e., the secondary flats, the structure and other optical, electronic, and electromechanical parts) are all within the existing manufacturing capabilities of the Large Optics Contractor and its vendors.

31.2.4.3.2 Subsystem and System Assembly

The facilities required for assembly of the interferometer and active mirror-actuator subsystems are all presently available at the Large Optics Contractor's facility. The assembly and alignment of the primary and secondary mirrors into the structure may be performed on the existing

12.19-meter optical bench located at the Large Optics Contractor's facility. However, a facility which would allow vertical assembly of the system would be preferred because of gravity-induced problems encountered in mounting the thin primary with the well structure horizontally. The Large Optics Contractor's facility could be modified to hold the experiment well structure vertically during mounting and setup of the thin primary mirror. Assembly and alignment of the active primary and the interferometer subsystem would then be performed in the horizontal position.

31.2.4.3.3 Subsystem and System Testing

All required functional and environmental tests for the interferometer and active mirror-actuator subsystem, as well as temperature and vacuum exposures of the bladder, could be performed on the Large Optics Contractor's facilities. However, optical measurements during temperature and vacuum testing would be limited. No new facility is recommended for subsystem testing, since subsequent system testing should yield all necessary information.

One of the areas to be studies in the prerequisite technology phase is feasibility of zero-gravity simulation. Depending on the results of this study, an additional facility may be indicated. Disregarding this possibility, all system functional testing described in the Preliminary Design, Development, Test, and Evaluation and Test Plans could be performed on the 12.19-meter optical bench or similar facility in a horizontal position. Dynamic testing of the system could be performed at the Large Optics Contractor facility and outside testing laboratory facilities. Temperature and vacuum testing for the system would require facilities such as the chambers located at Goddard Space Flight Center. Even these tests would be limited in scope, however, (particularly for the thin primary mirror) since complete testing requires the gravitational conditions of orbit.

31.2.4.4 Fine Guidance and Isolation Comparison Group Facilities Plan

31.2.4.4.1 General

The facility requirements for the Fine Guidance and Isolation Comparison Group of experiments, required for design, development, manufacture, and test prior to delivery to the launch facility, are discussed in this plan. The facility requirements of the Fine Guidance Contractor are presented first, followed by the Suspension System Contractor's requirements.

31.2.4.4.2 Fine Guidance Contractor's Facility Requirements

31.2.4.4.2.1 Manufacturing and Fabrication

The special facilities required for the manufacture and fabrication of the Fine Guidance Telescope are considered in this section. The fabrication facilities for the primary and secondary mirrors are analogous to the facilities described for the Laser Group of experiments; consequently, the vendors' facilities will suffice for this effort. The control moment gyros will be subcontracted to selected vendors, and all required facilities will be available at the vendors' plant. The remaining subsystems and components, while extensive and complex, are all within existing manufacturing capabilities at the Fine Guidance Contractor's facilities, with additional fixtures and instruments possibly required to supplement those presently existing.

31.2.4.4.2.2 Subsystem and System Assembly

The control moment gyros will be assembled at the subcontractor's existing facilities. The remaining Fine Guidance Telescope subsystems will be assembled at the Fine Guidance Contractor's facility; additional simulators and alignment stands may be required.

The alignment and assembly of the primary and secondary mirrors into the telescope will be performed on the Fine Guidance Contractor's 12.19-meter optical bench. With the addition of star simulators, the intermediate pointing and then the fine pointing subsystems can be installed and aligned in the telescope, on the same bench. The mounting and alignment of the star trackers to the telescope would require the addition of two more simulators and alignment telescopes to the 12.19-meter optical bench; one would be mounted along each of the axes of each star tracker. For simplification of alignment and boresighting, one tracker could be mounted pointing 180° from the telescope, and one at right angles to its axis. The alignment telescopes and simulators would require stabilities on the order of ± 0.5-minute-of-arc, and, therefore, could be mounted on alignment stands behind and to the side of the optical bench. Auxiliary optical elements, such as reference mirrors and pyramid prisms, would complete the additional equipment required for the assembly facility.

31.2.4.4.2.3 Subsystem and System Testing

All required functional and environmental tests for the subsystem could be performed on facilities available at the Fine Guidance Contractor's facility with the exception of the control moment gyro. This subsystem will be tested by the vendor at his facility; the Fine Guidance Contractor will assist in definition of the vendor's tests, and monitor their performance. Optical measurements on the subsystems during temperature and vacuum exposure may be limited by the chambers' constraints, but no new facility is recommended; subsequent system tests should yield all necessary information.

System dynamic tests could be performed both at facilities presently available at the Fine Guidance Contractor's facility, and at outside testing laboratories. Complete system functional tests, however, even excluding temperature and vacuum exposure, are limited by the impossibility of achieving measurements in the order of 0.01-arc-second on the ground. The best possible ground tests will be performed on an air bearing table facility, because they are nevertheless of value in checking out system performance. Other functional tests will be performed at the 12.19-meter optical bench, using the two auxiliary alignment telescopes previously discussed.

Temperature and vacuum tests can be performed in the same environmental chambers which are used for the laser telescopes, but optical measurements for the Fine Guidance Telescope in these chambers would be even more limited. In addition, information on the trackers' performance as part of the overall system would require chamber additions similar to those described above. With the available facilities, however, sufficient testing for assurance of proper function and orbital qualification is possible, and no new facilities are mandatory.

31.2.4.4.3 Suspension System Contractor's Facility Requirements

31.2.4.4.3.1 Preliminary Design, Development, Test, and Evaulation Requirements

To perform the operational tests on the subsystems and engineering models of the experiment, extensive simulation facilities will be required. Basically, it is required to simulate the low-g conditions of space and the mass properties and dynamics of the Fine Guidance Telescope. A plan for the development of these facilities is shown in figure 31.2.4.4.3.1-1, and is described below.

This plan is based on the simulation facilities already designed for the Prerequisite Technology program, but is more extensive. In the Prerequisite Technology program, only scaled models of the suspension systems are tested, only three degrees of freedom (one rotation and two translation) are provided, and only the Intermediate Loop dynamics of the telescope stabilization system are simulated. The full effects of these constraints will not be known until the Prerequisite Technology program is completed. However, for purposes of developing the schedule shown in figure 31.2.4.4.3.1-1, it is assumed that the required facilities differ from the Prerequisite Technology facilities only in that full-scale engineering models of the experiment must be tested.

31.2.4.4.3.2 Design

The Preliminary Design, Development, Test, and Evaluation facilities are made up of five subsystems: the suspension test fixture, which provides the low-g, low-friction environment for testing the suspension system; the disturbance environment simulator, which excites the suspension systems to simulate the disturbance environment of the spacecraft; the telescope dynamic simulator, which simulates the mass and stabilization properties of the telescope; the instrumentation system, which measures and verifies the test results; and the environmental control system, which provides the stabilized environment in which precision measurements can be made.

31.2.4.4.3.2.1 Suspension Test Fixtures

This subsystem consists of a seismic foundation isolated from the plant floor, a support structure for holding the suspension systems, and a leveling system for providing a low-g environment in a single plane. Because

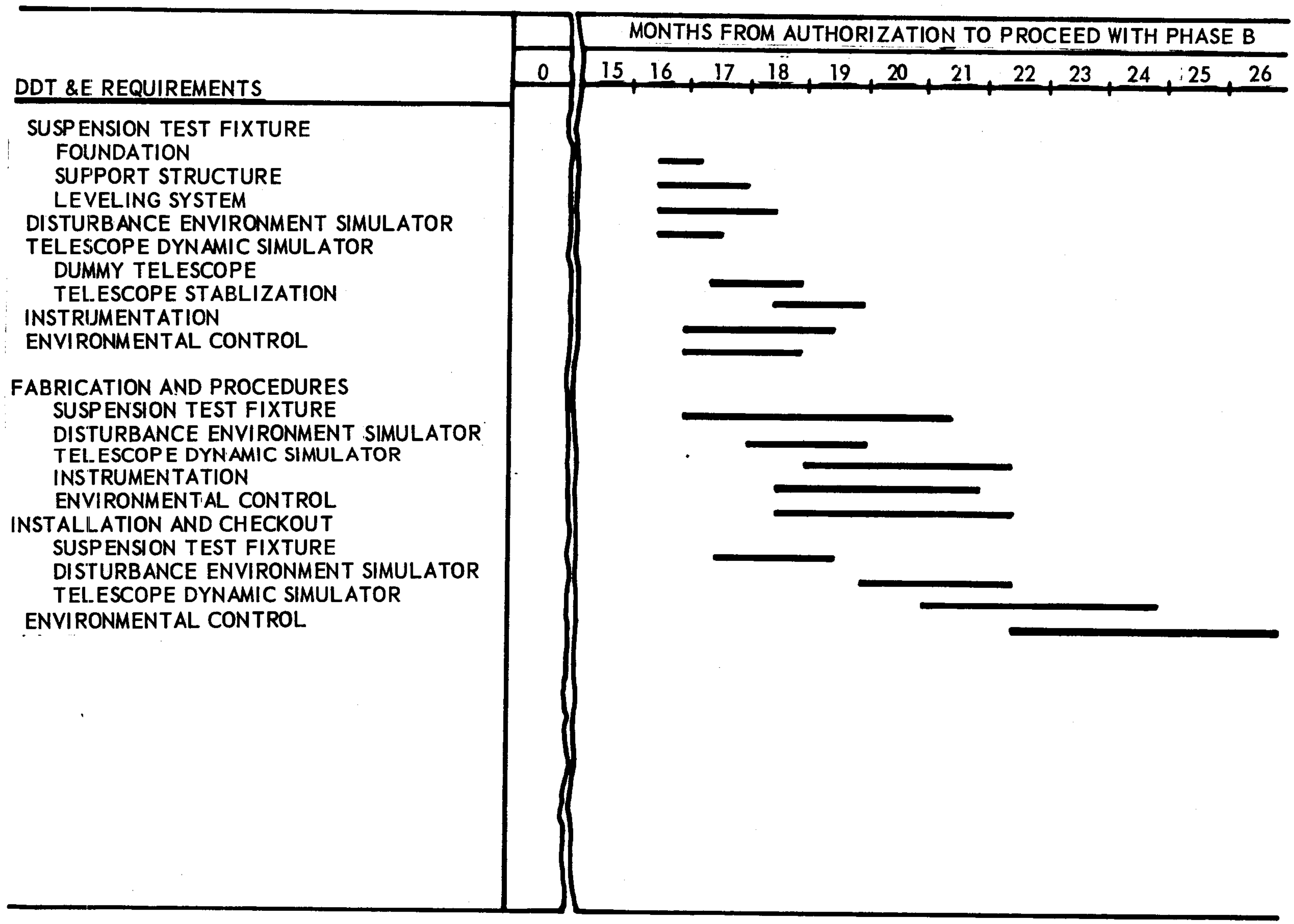

Figure 31.2.4.4.3.1-1. Suspension System Facilities Schedule

working models of these components will have been developed in the Prerequisite Technology program, the design will be straightforward and can be initiated immediately after Authorization to Proceed - Phase B.

31.2.4.4.3.2.2 Disturbance Environment Simulator

This subsystem is composed of a structure to represent the spacecraft well and an exciter which drives the suspension system being tested in accordance with a predetermined disturbance profile. The design of this subsystem will be straightforward if the system is driven only with standard sine, step, and random functions. If it is decided to drive the system with arbitrary time functions to more closely simulate the actual spacecraft disturbance environment, then the design of the function generator will take longer than that indicated in figure 31.2.4.4.3.1-1.

31.2.4.4.3.2.3 Telescope Dynamics Simulator

This subsystem is comprised of the dummy telescope and the telescope stabilization system. The dummy telescope should have the same rigid-body properties as the Fine Guidance Telescope, to create the proper load on the suspension systems. In addition, the elastic properties of the Fine Guidance Telescope should be at least partially simulated, because the low, model frequencies will probably fall within the telescope control bandwidth.

It is assumed here that the telescope stabilization is represented as a single control loop, the Intermediate Loop of the Fine Guidance Telescope. The reason for this assumption is the anticipated difficulty of testing the Fine Loop in a groundbased test environment. However, experience in the Prerequisite Technology program will show whether testing of the fine loop is possible in the controlled environment of the test lab. If so, the design of the telescope stabilization subsystem will take longer than indicated in figure 31.2.4.4.3.1-1.

31.2.4.4.3.2.4 Instrumentation

This subsystem consists of an angle readout system which measures the position of the platform (independent of the error angles of the telescope stabilization system), and the controls and displays of the entire test laboratory. The complexity of this instrumentation, and the time span shown in figure 31.2.4.4.3.1-1, will be increased if the Fine Loop is tested.

31.2.4.4.3.2.5 Environmental Control Subsystem

The environmental control subsystem will maintain uniform temperature and minimize adverse environmental conditions in the test laboratory. The timespan shown in figure 31.2.4.4.3.1-1, like that for the two subsystems above, is predicated on the requirement to test only the Intermediate Loop dynamics.

31.2.4.4.3.3 Fabrication and Procurement

Generally, the entire facility will be designed and fabricated by the Suspension System Contractor, with the exception of the instrumentation that will be purchased from selected vendors, and a few special items such as the table leveling actuators which will be subcontracted.

The long lead items for the facility will be the granite surface plate, which must have a special laboratory finish over a large area, and some components of the table leveling system. Procurement of these components, therefore, will be initiated at the start of the design phase.

31.2.4.4.3.4 Installation and Checkout

Installation and checkout will include the assembly and checkout of individual subsystems where applicable, and the installation of the facility as a whole. Provision is made in the schedule for some redesign. However, if the decision is made to test the dynamics of the Fine Pointing Loop of the telescope stabilization system, then the time spans as a whole must be increased by at least 50 per cent.

31.2.4.4.3.4.1 Manufacturing

Manufacturing of all structural components will be performed at the Prime Contractor's plant. No new facilities of significance will be required for this purpose. Manufacture of suspension system components such as springs, electromagnets, accelerometers, and all electrical instrumentation will be subcontracted to selected vendors.

31.2.4.4.3.4.2 Subsystem and System Assembly

All assembly will be performed at the Prime Contractor's facility. No special facilities will be required for this purpose, because presently existing facilities are adequate.

31.2.4.4.3.4.3 Subsystem and System Test

The subsystem and system operational tests will be performed at the Suspension System Contractor's test facilities as described in the Preliminary Design, Development, Test, and Evaluation Requirements, and in accordance with the DDT&E test.

31.2.4.4.4 Cost and Scheduling

The facilities cost for the Fine Guidance and Isolation Comparison Group of experiments is estimated to be $312 thousand. The facilities described will be required 26 months from Authorization to Proceed - Phase B.

31.3 SPACECRAFT RELATED PLANS

31.3.1 Preliminary DDT&E Plan

31.3.1.1 Introduction

Spacecraft configuration No. 1, a modified lunar module (LM), consists of nine principal subsystems, as depicted in figure 31.3.1.1-1. This configuration is an effort to make maximum use of Apollo hardware. The concept consists of a modified LM ascent stage with both a platform and a telescope support structure for attachment and integration of the experiments. The LM descent stage is removed as is the ascent stage propulsion system.

Preliminary cost data have been developed to provide gross estimates of the total DDT&E activity, including fabrication of both the prototype and the structural test unit. The DDT&E effort is expected to cover a 36-month time span at a total cost of $54,200,000.

31.3.1.1.1 Design and Development

The major items which will require attention for the design and development of the spacecraft in the subsequent phases are: 1) analysis and final configuration requirements, 2) preliminary design, 3) preliminary layouts, 4) development testing, 5) detailed design, and 6) qualification (see figures 31.3.1.1.1-1 and -2). The design must meet the objectives of mission, reliability, and ease of fabrication and assembly. Detailed analysis of the final design will be made to ensure subsystem integrity and compatibility. Throughout the detail design of the system, periodic formal design reviews will be conducted with the principal functional and management elements participating in the program. Quality engineers will review the design to establish the quality and reliability of the system. These reviews will not take the place of normal engineering design coordination and integration activities; rather, they augment these activities and input the requirements of the other functional elements of the program into the design. Layouts will be used to establish the validity of the preliminary design, highlight corrections and changes, establish those design items most suitable for subcontracting, and facilitate the writing of specifications and work statements.

The final design will meet the following criteria:

a. Reliability and safety requirements

b. Functional Design

c. Economically manufactured hardware

d. Adequate production schedule

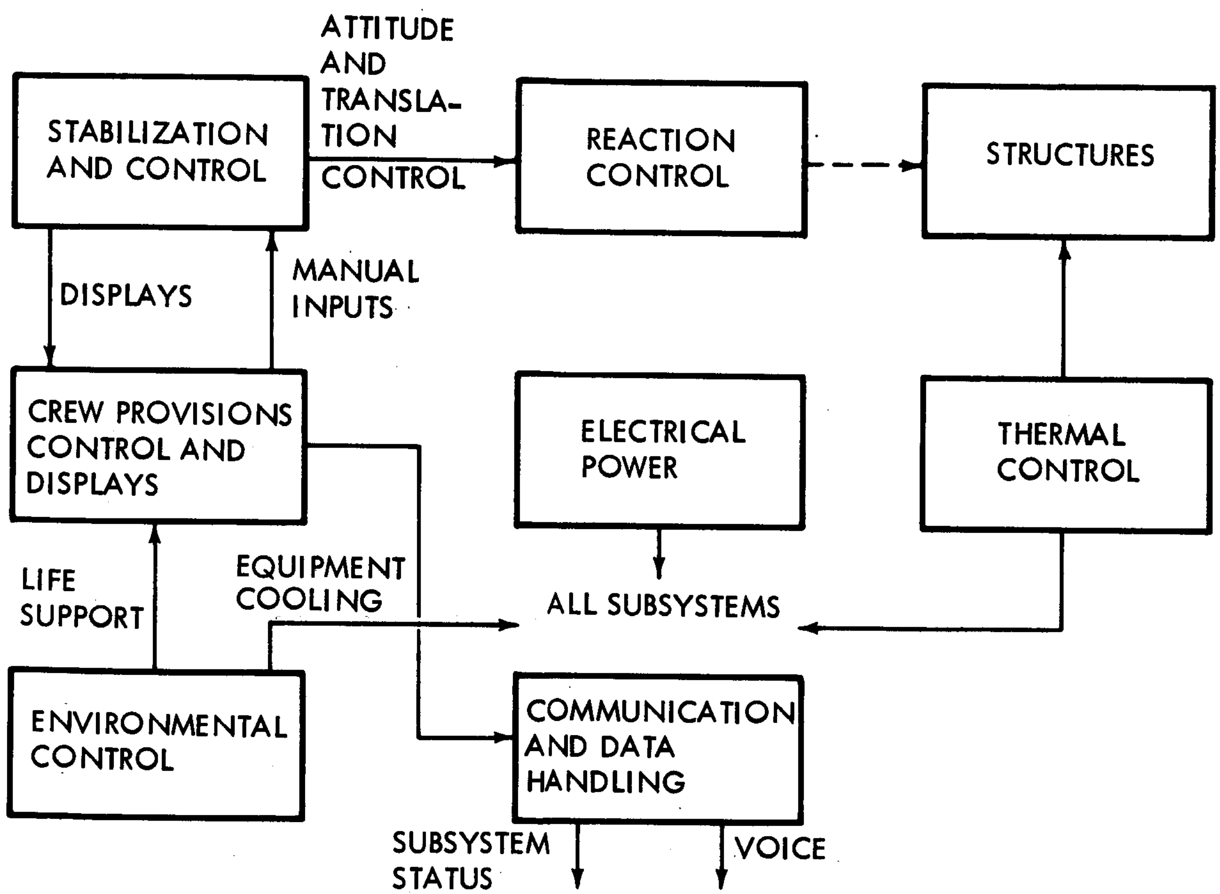

Figure 31.3.1.1-1. Subsystem Functional Relationships

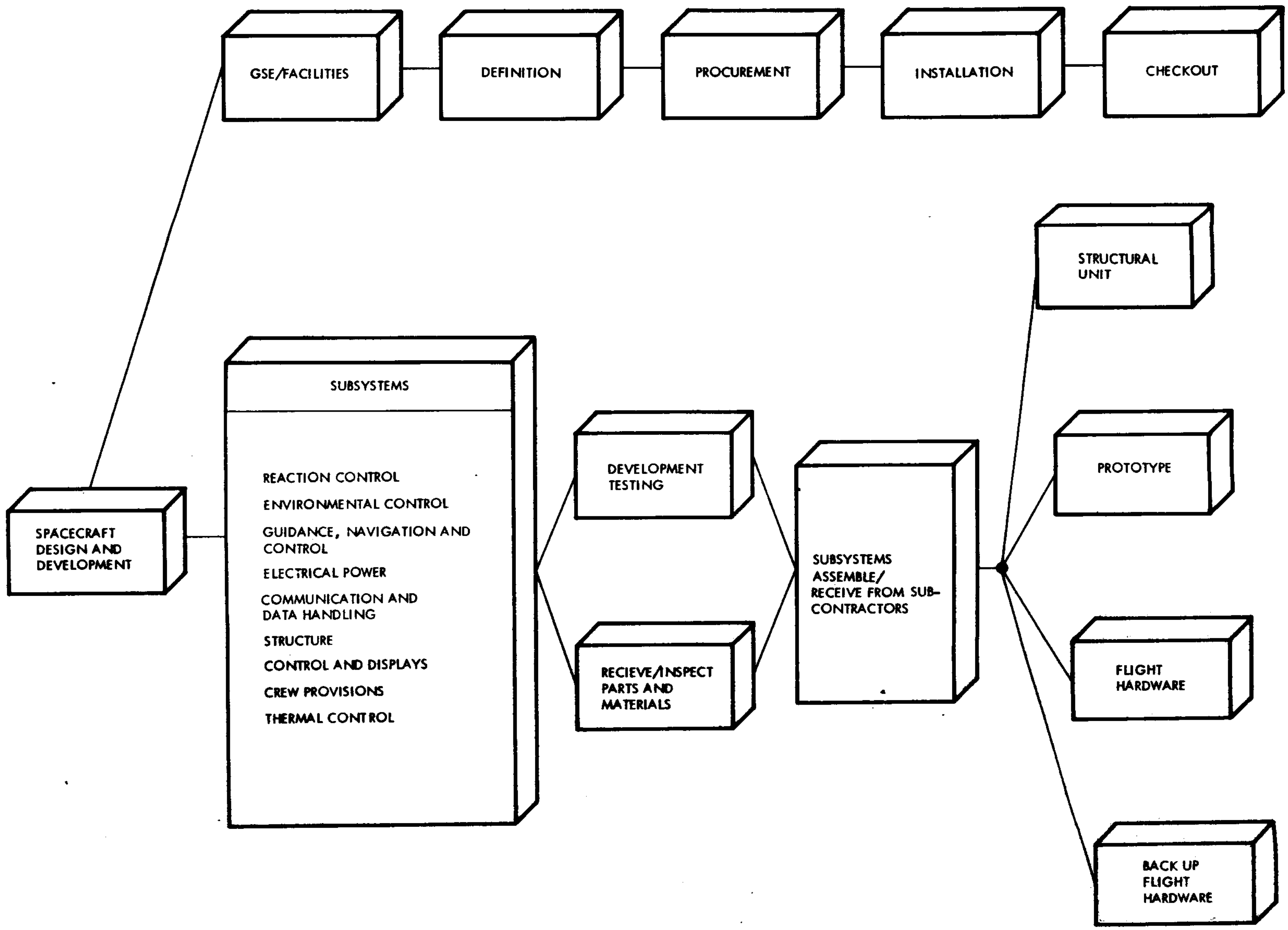

Figure 31.3.1.1.1-1. Spacecraft Development Diagram

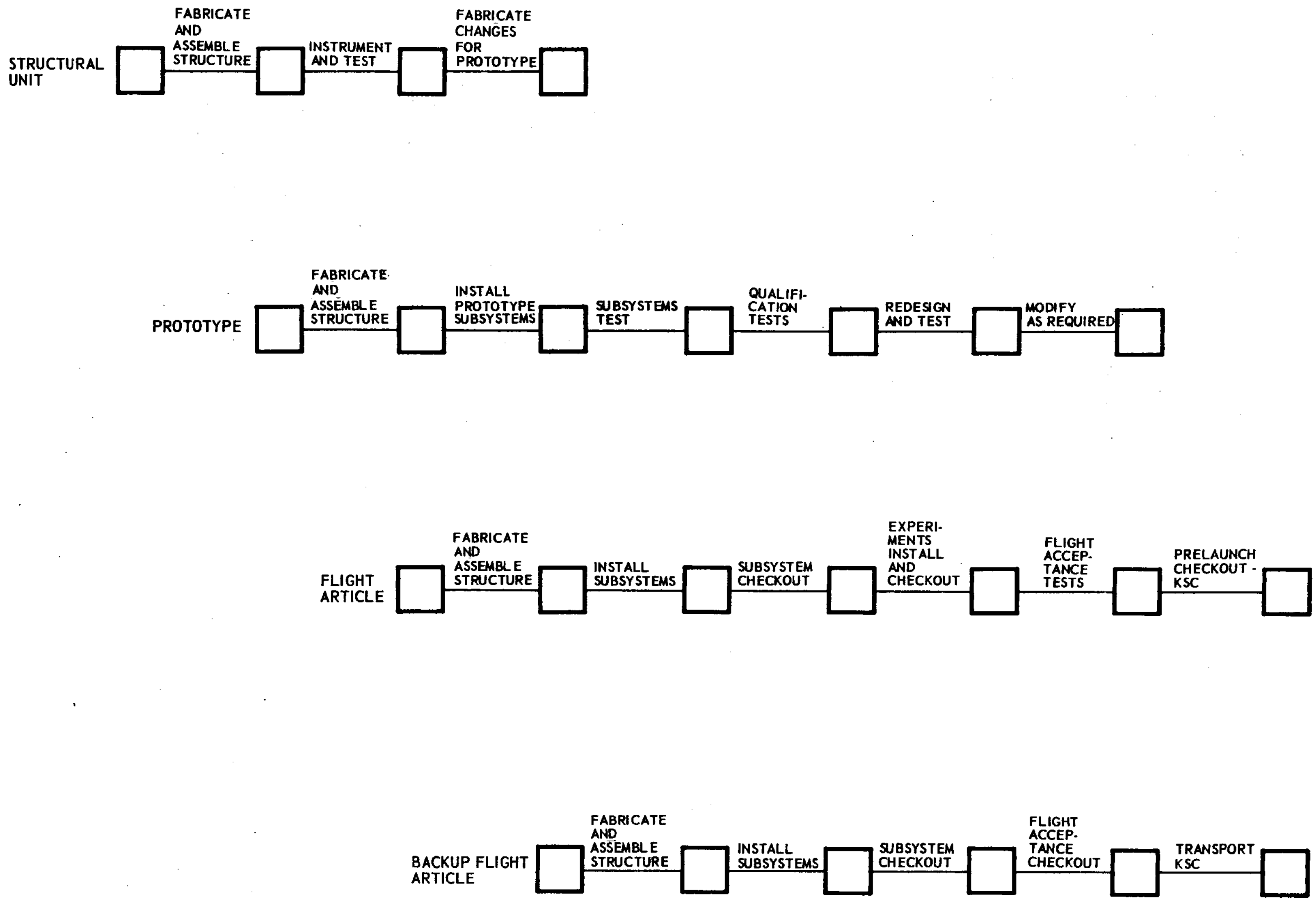

Figure 31.3.1.1.1-2. Spacecraft Flow Diagram

31.3.1.1.2 Test Philosophy

Before the spacecraft configuration can be committed to a manned mission, its ability to meet the operational requirements of the mission must be demonstrated to assure both astronaut safety and mission success. To achieve these results, it is necessary to develop a complete and integrated test program which will provide for the correction of unanticipated design problems prior to design release and qualification.

The test requirements that will be presented in this plan include only that testing which will be done on prototype or test hardware. The testing requirements on the flight hardware are presented in the preliminary test plan.

The test requirements for this plan are grouped into three main categories:

a. Development tests

b. Qualification tests

c. Reliability tests

31.3.1.1.3 Development Testing

Development testing includes all tests that are required not only to determine the feasibility of the design approach but also to evaluate hardware performance. These tests must identify all potential causes of unreliability and eliminate them early in the design stage. In this way, design deficiencies and areas of program degradation can be eliminated. Necessary subsystem breadboard models will be produced early in the design stage. The tests performed on these models will generally be used to verify the functional performance of a design as development proceeds. Prototype components will be built to preliminary drawings and specifications, and will represent the intended production article as closely as possible. To ensure adequate performance test results on prototype equipment, test criteria must correspond to actual design requirements and performance criteria. Modification that results from evaluation of the test results will be immediately introduced into the design. The operational status of each subsystem will be verified before that subsystem is operated concurrently or in conjunction with an interface system. However, reasonable costs and schedules will be achieved by confining testing to areas where performance doubt exists, or where adequate assurance cannot be provided by analysis and critical evaluation. A reporting and documentation system will ensure that all failures are carefully explained and that corrective action is taken when required.

31.3.1.1.4 Qualification Testing

These tests will be conducted to demonstrate that hardware design specifications are met when subjected to an operational environment. Subsystem tests utilizing the final flight configuration will provide final qualification of subsystem design. These tests will provide confidence that all the components function correctly as part of the total system. Where possible, development and qualification tests will be performed on the same test article, either sequentially or simultaneously. However, breadboard articles are not acceptable for qualification testing. It is not intended that separate qualification tests be conducted in all cases; qualification may possibly be the end result of a successful evaluation test. By this method, the result will be the elimination of costly testing duplication. Comprehensive test documentation, including the results and evaluations, will be maintained on all qualification tests.

31.3.1.1.5 Reliability Testing

These tests will be necessary to establish a significant level of engineering confidence in the reliability of the hardware. All elements of the OTAES spacecraft share the problem of meeting extremely high reliability goals that must be attained by a manned spacecraft in the presence of a hostile space environment.

The development test phase must identify all potential causes of unreliability and eliminate them early in the program. The qualification test phase will verify that this process has been effectively accomplished and that the components and systems will work together in the anticipated environments. Reliability data will, therefore, be generated by all of these spacecraft tests. Special reliability testing will be initiated for particularly critical items, or for equipment for which development and qualification testing have not adequately demonstrated the prescribed reliability confidence level.

31.3.1.2 Subsystems

31.3.1.2.1 Propulsion and Reaction Control Subsystem

31.3.1.2.1.1 General

The reaction control subsystem (RCS) will be used for Δv correction, for station keeping, for attitude control during maneuvering, and for desaturation of momentum storage devices. The RCS considered for the OTAES spacecraft is an entirely different system from that which is on the present lunar module (LM) ascent stage. However, the OTAES RCS will utilize components which have been developed and qualified in other space programs, thus minimizing development and qualification cost and lead times. The RCS consists of 2 or more propellant tanks which feed to a common manifold and supply fuel to 16 thrusters. Each thruster provides 0.5 to 1.0 pounds of thrust, using a hydrazine monopropellant with a Shell 405 catalyst. The thrusters will be mounted in clusters of four using the same mounting position as the present LM RCS.

31.3.1.2.1.2 Design

The proposed design for the RCS is based on current design techniques. The design requirements for the RCS will be established. These requirements include total impulses, thrust levels, critical flow valves, line sizing, pressure drops, etc. These design requirements will form the basis for the preliminary design of the RCS and support facilities, and will be sufficient to permit the preparation of detailed procurement specifications. The preliminary design will be adequate to determine the preliminary subsystem layout. These layouts will determine not only the availability of space for line routings, packaging arrangements but also what the interface requirements will be.

Breadboard testing will be initiated as soon as possible. Subsystem problems, therefore, can be uncovered early, and required modifications to either the design or the hardware can be implemented at the earliest possible date. All hardware tested will be full scale. Most of the components used in the RCS will be off-the-shelf items, but there are some component materials that will require evaluation for ability to function after long-term exposure to hard vacuum, radiation, and propellant. A critical item is the propellant tank bladder material. It will be necessary to conduct a detailed investigation on the effects of long-term radiation on butyl-rubber bladders from available analytical and test data, and to research other materials such as reinforced teflon bladders. Another area of concern which must be resolved during development testing is the evaluation of thrust-chamber pressure and the effect of subsystem parameters on its performance. Design criteria must include subsystem compatibility, system transients, environmental effects, and fundamental operating procedures.

31.3.1.2.1.3 Test Requirements

Testing will include, but not be limited to: 1) single and clustered engine tests to determine performance and operation of the RCS in various modes, 2) environmental tests to determine the effect of environment on the RCS, and 3) system leak checks.

A completely assembled RCS will be qualification tested to ensure the successful demonstration of system operation, and to ensure the satisfactory performance of the subsystem within the established functional specifications.

The RCS thrusters will be fired under space conditions as part of the qualification program. A small static test facility will be required which will be capable of providing the conditions necessary for vacuum ignition of the engines. At least two other facilities are required for adequate testing of the RCS. A burst and proof test chamber for pressure testing of the titanium propellant tanks, and a space simulator which must be capable of simulating solar radiation and free space temperature. The space simulator is also necessary so that the effects of the thermal environment on propellants, seals, and joints can be determined.

31.3.1.2.2 Environmental Control Subsystem

31.3.1.2.2.1 General

The following paragraphs present a preliminary analysis of the environmental control subsystem (ECS) being considered for the OTAES spacecraft. The major functions to be performed by the ECS are pressurization, ventilation, temperature, humidity, and control of the contamination level in the spacecraft cabin, access compartment, and astronaut pressure garment assembly. The ECS also provides thermal control both for the spacecraft electronic equipment and for experiments requiring active thermal control.

The design parameters and mission profile consists briefly of the following: 45-day manned mission; 3-man crew; shirt-sleeve environment; 2-gas system (70 per cent oxygen and 30 per cent nitrogen) at 5 psia cabin pressure.

31.3.1.2.2.2 Design

The subsystem design for the ECS is based on present state-of-the-art components and concepts, making maximum use of existing hardware being used on the present lunar module. Modifications to the existing hardware will be made, where necessary, to meet the specific OTAES requirements. Primary changes to the subsystem will include: resizing and storage method for the atmospheric supply section; utilization of a 2-gas system and its necessary controls; a thermal loop which will make use of radiators and associated equipment in place of water boilers; molecular sieves with a LiOH backup cannister for control of CO_2; and water management redesign.

The modified ECS consists of five sections. The following is a brief description of these sections and the design changes that will be necessary to convert the lunar module ECS to an OTAES ECS.

a. Atmospheric revitalization

b. Cabin thermal control

c. Atmospheric supply and control

d. Water management

e. Atmospheric storage

31.3.1.2.2.2.1 Atmospheric Revitalization

The atmospheric revitalization section conditions and provides the atmosphere to cool and ventilate the pressure garment assembly (PGA), and monitors cabin oxygen recirculation and temperature. This section monitors the carbon dioxide level of the atmosphere breathed by the astronauts, removes odors and noxious gases from this atmosphere and maintains relative humidity within specified limits. The section consists of heat exchangers, filters, water reclamation apparatus, blowers, and molecular sieves. The main design concern in this area is the increase in capability of the system from a 2-man level to a 3-man level. Careful analysis of this area has been made, and it was found that the subsystem will be capable of supporting three men with no hardware changes deemed necessary.

Although hardware changes are not required a problem area exists which will require careful analysis. The storage of enough LiOH to remove CO_2 from the atmosphere to meet the 45-day manned mission requirement would cause difficult volume and weight problems. A desirable tradeoff would be to utilize molecular sieves instead of the LiOH.

31.3.1.2.2.2.2 Thermal Control

The thermal control section provides for active thermal control for atmospheric, experimental, and electronic equipment. The present LM ECS makes use of water boilers for heat removal; however, because of mission duration and in order to prevent possible contamination to optical systems, the water boilers will be replaced and a radiator assembly inserted. The design of an optimum radiator configuration involves numerous parametric variables. Similarly, additions or deletions of thermal loads to existing cold plates is a subject of extensive analysis. It is, therefore, necessary that contemplated increases or decreases in thermal requirements, because of experimental or subsystem changes, be analyzed and made a part of the design requirements as soon as possible. For any given radiator control system, heaters may be needed during minimum load periods.

31.3.1.2.2.2.3 Atmospheric Supply and Control

This section provides and regulates the cabin and spacesuit atmosphere requirement. It must also provide for controlled pressurization of the access compartment and provide oxygen to refill the portable life support system (PLSS). It is necessary to make modifications in this area because of the change to a 2-gas system. Components will be added to the subsystem to supply the nitrogen gas and to control the partial pressures of the two gases.

31.3.1.2.2.2.4 Water Management

The water management section stores potable water for the metabolic needs of the astronauts, spacecraft evaporative cooling, and PLSS water tank fills and refills. Modifications to the present LM configuration will be reflected by the removal of the water boilers from the thermal control loop, and the removal of storage bottles carried in the descent stage. It will be necessary in preliminary design to consider an increase in storage capacity in view of the present mission definition.

31.3.1.2.2.2.5 Atmospheric Storage

The atmospheric storage section will provide the demand supply of atmospheric gas required to make up for leakage, repressurization, or astronaut metabolic needs. It will consist of gas storage bottles, pressure regulators, and associated plumbing. Because atmospheric storage is the heaviest and bulkiest portion of the ECS, the sizing and packaging of this section will be an important design consideration.

31.3.1.2.2.2.6 Test Requirements

31.3.1.2.2.2.6.1 Development Tests

During the ECS development testing phase, previously qualified, applicable LM components will undergo only those development tests necessary to verify the ability of the item to meet the slightly different requirements of OTAES. Performance, calibration, operational, and electrical tests will be conducted on the LM components, as necessary.

Modified and new programs will have more extensive tests conducted during the development phase. Comprehensive development tests will be divided into four major categories for these items: performance, environmental, life, and functional testing. Production or prototype parts and components will be used to construct a breadboard model of the ECS. The following types of functional tests will be performed with the ECS breadboard.

a. Coolant flow rates

b. Heat transfer characteristics

c. Power requirements

d. Control response (temperature)

e. System balance

f. Cabin temperature controls and pressure regulation

g. Overall operation

Environmental testing on the breadboard will be limited to thermal vacuum tests. Objectives of the test will include:

a. Heat rejection rates

b. Pressure drop in coolant loop

c. Temperature variations of equipment on cold plates

d. Thermal balance

e. Range in variation of each of the 4 items above

f. Calibration of variable controls

g. Functional performance in redundant modes

31.3.1.2.2.8.2 Qualification Test

Prior to the initiation of qualification testing, all components will undergo a series of tests and a prequalification performance record to ascertain that they have been manufactured and assembled in accordance with specifications and that they are ready to undergo a qualification program. These tests are basically the examination of product, weight, proof pressure, leakage, and calibration.

To minimize schedule and cost, qualification tests will be eliminated when similar and adequately verified test data are available. It is anticipated that requalification for vibration and shock will not be required except for new components. Proof pressure and leakage tests will be performed on all items during qualification.

31.3.1.2.3 Guidance, Navigation, and Control Subsystem

31.3.1.2.3.1 General

The guidance, navigation, and control subsystem on the OTAES Spacecraft will include equipment used to establish reference coordinate systems, to indicate attitude of spacecraft, to change attitude of spacecraft axes to reference coordinate axes, and to define uncertainties in vehicle position, velocity, and attitude.

The function of the guidance, navigation and control subsystem installed on the lunar module is to control the vehicle during descent from lunar orbit to the lunar surface, to track the CSM during the lunar stay, to control the ascent stage of the lunar module during ascent from the lunar surface, and rendezvous with the CSM. The function of the guidance, navigation, and control subsystem installed on the OTAES vehicle is to control the attitude of the spacecraft in a very stable manner during the optical experiments. Because these functions are so dissimilar, it will be necessary to completely remove all LM guidance, navigation and control components (except possibly the general purpose computer and displays and control panel), and replace it with equipment tailored for the OTAES mission.

31.3.1.2.3.2 Design

There are three reference coordinate systems of interest in earth orbital flight. One is based on earth, another on the sun, and a third on our star system. The reference system desired and the type of onboard equipment needed to establish it will depend upon the application - i.e., whether earth based as in the laser communication experiments, or stellar based as in the fine guidance experiment. Navigation methods also depend upon accuracy and stability requirements.

Navigation equipment required for OTAES will include:

a. A sun sensor system to establish pitch and yaw with respect to the sun

b. A horizon scanner to establish pitch and roll with respect to the earth

c. An inertial guidance system to establish roll, pitch, and yaw with respect to the inertial space

d. Two star trackers to establish roll, pitch, and yaw in stellar space

Control in the guidance, navigation, and control subsystem will be accomplished by means of a monopropellant hydrazine reaction control system and control moment gyros. In this context, control refers only to spacecraft changes of attitude while in a chosen orbit; it does not include Δv changes for changing total orbital momentum.

31.3.1.2.3.2.1 Solar Sensors

The solar sensor navigation system will consist of eight wide-angle (90°) sun sensors, nine narrow-angle (20°) sun sensors, electronic balancing circuitry, an amplifier, and a display panel. Two pairs of wide-angle sensors and two pairs of narrow-angle sensors will be located externally at each end of the spacecraft on the X-axis. The ninth narrow-angle sensor is a disabling eye used to shut off the wide-angle sensors' electronics after sun acquisition.

The sensor may be used in either an automatic sun acquisition mode or in a manual control mode. In the automatic mode, output from the amplifier instructs the reaction jet system to move the spacecraft X-axis by a series of discrete motions until it coincides with the spacecraft-sun axis. In the manual mode, a crew member will manually steer the spacecraft to the desired orientation by observing spacecraft attitude on the sun sensor control and display panel.

Solar cells are now on-the-shelf items and are typically about 2-inches in diameter, 2 inches deep, and weigh about 1 ounce each. The total sun sensor section including electronics will weigh about $6\frac{1}{2}$ pounds. An evaluation is being made to determine whether production units will fulfill requirements or whether special units must be developed. If new units are to be developed, it will be necessary to perform environmental testing to MIL-STD-810A Methods 500.1, 511.1, 513.1, 514.1, and 517.1. These test, respectively, for low pressure, explosive atmosphere, acceleration, vibration, and low-pressure solar energy. The only required equipment not currently available at the Michoud Assembly Facility is a solar simulator. Equipment will be subjected to the low-pressure and low-pressure solar energy tests for a period equal to the anticipated length of mission.

For the electronic equipment, development and qualification tests will be similar to those for sensor elements with the following exception: test 517.1 will be dropped and test 515, Acoustical Noise, will be added.

31.3.1.2.3.2.2 Star Tracker

The star tracker fixes on any star of +10 magnitude or brighter located within $\pm$ 45° of the star tracker null axis. The system may be used as a backup to other attitude reference systems, but its prime function is to align the spacecraft attitude for stellar oriented experiments. The star tracker consists of two gimbaled telescopes with the capability of electronically centering stars in their respective 1° by 1° fields of view. As with the solar sensors, either manual or automatic mode may be selected to place a star in the star tracker's field of view. As there are currently available production star trackers with an accuracy equal to that required for OTAES, development of a star tracker for the OTAES mission should not produce any technical surprises. Kollsman K-137 Tracker, as used in Orbiting Astronomical Observatory I (launched April 8, 1966), could be used with only minor changes in detail. Two star trackers with electronics will fit into a space 17.5 inches by 16.75 inches by 16.25 inches and will not weigh more than 40 pounds.

Qualification of the system will include the same tests as required for the solar sensors system plus an accuracy test using a star simulator.

31.3.1.2.3.2.3 Horizon Scanner

A horizon scanner will give roll and pitch axes by tracking local vertical. Tracking is accomplished by detecting the difference between thermal radiation emitted by earth and its atmosphere, and thermal radiation emitted by free space. The horizon scanner consists of an optical system to image the earth on a detector, a scanning system to move the field of view in a fixed pattern relative to the spacecraft, and an information processor to provide truth or error signals to both the scanner, and the control and display panel.

There are currently available several types of horizon scanners with possible applications to the OTAES spacecraft. All types are similar but differ in scanning mechanism. Mission analysis will continue in order to determine the optimum scanning method for OTAES application. The complete scanner will weigh less than 13 pounds and occupy a space of less than 1/3-cubic foot.

A problem which must be overcome with any scanner configuration (especially for high-altitude orbits) is the potential presence of high-intensity radiation from the sun in the field of view. In addition to generating errors, the sun might damage detector elements. A means to determine the sun's presence and block its radiation must be provided.

Qualification of the horizon scanner will require the same test methods of MIL-STD-810A to be used for the solar sensor system. An additional test for accuracy using an Earth simulator will be required.

31.3.1.2.3.2.4 Inertial Guidance System

The inertial guidance system will use six strapped down, rate integrating gyros. Three of the gyros will be arranged in one orthogonal set. The other three will be mounted in an orthogonal set skewed to the others. Error signals from the gyros will be analyzed by the guidance computer which will then deliver appropriate voltage outputs to the control system and manual control displays to provide:

a. A fixed attitude reference with respect to inertial or orbital space

b. Angular rate signals about each control axis

c. Signals for driving the attitude displays

d. Signals which can be used to maneuver and point the vehicle

A difficulty imposed by the strapped down inertial guidance system is the stringent requirement on the guidance computer. A study is being conducted to determine whether it will be feasible to use the general spacecraft computer to perform the calculations, or whether it will be necessary to develop a separate guidance computer. Even though the computer requirements are increased over requirements for a gimbaled gyro system, the favorable size, weight, reliability, accuracy, sensitivity, and power characteristics of the strapped down system outweigh any disadvantages it might have. Total weight of gyros including control assembly will be less than 35 pounds and will occupy a space of less than 1 cubic foot. The gyros alone will be approximately 2 inches in diameter and 3 inches long.

Development and qualification test will require a subsystems breadboard performing all flight functions under a simulated space environment for length of flight duration. MIL-STD-810A with test methods for low pressure and solar pressure deleted may be used for space simulation tests. An accuracy test to establish drift rate will be required.

31.3.1.2.3.2.5 Control Moment Gyros

Control moment gyros were chosen over other candidate continuous momentum storage devices on the basis of their lower weight and power consumption. A thorough analysis based on mission plan, spacecraft shape, and mass distribution will be required prior to selecting an optimum control moment gyro subsystem. A preliminary analysis indicated the maximum expected disturbance torque on the spacecraft during the experimental portion of flight to be 11 foot-pounds. Three orthogonally mounted gyros, having angular momentums of 1000 foot-pound-seconds, will be able to handle a disturbance of that magnitude. Sizing studies indicate a total system weight of 270 pounds.

Final development of control methods will require analog simulation techniques. Development must include operation of the subsystem both in a simulated space environment and under the complete dynamic flight range.

31.3.1.2.3.2.6 Displays and Manual Controller

Crew members will be able to determine attitude and make desired changes by using the displays and manual controller console. Displays will include:

a. Star tracker

b. Sun sensor display

c. Flight attitude indicator

d. Horizon scanner display

e. Gyro panel

f. Fine guidance control panel

g. Checkout keyboard readout

Controls will include:

a. Mode control panel

b. Rotational controller

c. Reaction control panel

Both displays and controllers are available hardware. In order to ensure high reliability, however, it will be necessary to test each unit for accuracy under long-duration, severe environmental conditions.

31.3.1.2.4 Electrical Power Subsystem

31.3.1.2.4.1 General

The OTAES spacecraft electrical power subsystem provides all of the electrical power to operate the electrical equipment of all the spacecraft subsystems, including the experiments. The power subsystem is divided into two classes, Class A and Class B. Class A is a fuel cell system which will encompass all loads necessary for manned operation, including equipment such as the environmental control subsystem and cabin lighting. This power is necessary only for the manned duration of the mission. Class B power, a solar cell system, includes all loads that are necessary to maintain the spacecraft and the experiments. The equipment requiring power from this system includes command and control, communications and data handling, and displays. This power will be required for the life of the mission, manned and unmanned.

The power subsystem currently available on the baseline spacecraft is not satisfactory to meet the requirements of an OTAES mission. Therefore, an entirely different subsystem will be required using present state-of-the-art components and technology.

31.3.1.2.4.2 Design

31.3.1.2.4.2.1 Fuel Cell System

Fuel batteries are favored because the load profile for the manned mission calls for moderate power over a fairly long period of time (45 days). Some of the advantages of a fuel cell battery system are:

a. High power rating for unit volume and weight

b. High efficiency

c. Low-cost fuel and oxygen

d. Long life

The design considerations that must be made in developing this system are not simple, and they must be made on the basis of the complete energy system for the load profile in question. For example, one must consider energy source plus fuel and oxygen, plus all of the peripheral equipment. In order to handle high peak loads, silver cadmium storage batteries will be used and kept charged by the fuel cells in continuous operation.

The design approach for the system described assumes that the fuel battery will meet the following criteria:

a. The electrochemical elements of the fuel battery must operate at the highest power density compatible with structural simplicity, high reliability, light weight, and insensitivity to environmental factors such as acceleration and zero gravity.

b. The mechanical structures must be simple, light, and reliable.

c. The means of removing by-product water and heat must function to maintain effective fuel cell operation. They should be extremely simple, reliable, and operate at zero gravity.

d. The supporting components (reactant and electrical controls) must match the fuel battery's inherent simplicity while ensuring required output within specified voltage limits.

The fuel battery consists of the following elements:

a. The individual fuel cells, assembled in stacks and groupings of stacks (sections)

b. The containing structure

c. The reactant (fuel and oxidant) supply, including provisions for removal of inert gases (purging)

d. By-product water removal and storage

e. Heat removal

f. Controls (reactant and output)

The reactants are supplied from super-critically stored hydrogen and oxygen containers. The main supply from these storage tanks is divided to supply each fuel cell stack independently. Each oxygen supply is similar to the hydrogen supply in that oxygen is regulated and filtered in the section inlet line.

A small percentage of the reactant gases must be expelled from the system periodically to ensure that any impurities contained in the feed gases do not accumulate, thereby restricting reactant feed to the cells.

The reaction of hydrogen and oxygen within the fuel cell manifests itself in three forms: electric power, water, and waste heat.

Transport of water within the fuel battery and its separation from the reactant gas environment may be achieved by use of capillary action and differential pressure. As a result, the management of product water requires no moving parts and is not affected by gravitational forces.

Proper design techniques can minimize the possibility of a failure which would bring the two gases together under combustible circumstances, and can limit the damage resulting from such a failure, should it occur. Some of the design features which would contribute to safe operation are:

a. Operation at low pressure and low temperature, reducing the chance of leaks and ruptures

b. Keeping volume of reactants in the fuel battery to a minimum

c. Accidental mixing of reactants would take place in the presence of a catylist which would cause the gases to react completely and turn to water.

31.3.1.2.4.2.2 Test

Objectives of fuel cell battery system development testing are to determine the performance of a fuel cell battery system in terms of reliability, operability, and maintainability; compatibility with other subsystems of the spacecraft; and operation of ground test equipment during fuel cell system checkout. Typical tasks which are performed during the test program include:

1. Preinstallation tests to insure functional integrity.

2. Checkout and support system tests with the fuel cell battery as part of the spacecraft to determine compatibility and flight readiness.

3. Perform special tests to support the evaluation and improvement of the fuel cell spacecraft system.

4. Collect and transmit test data for analysis.

Special tests covering a broad range of system capabilities and qualifications for space flight will be conducted, as required.

31.3.1.2.4.3 Class B Power

The complete Class B power subsystem consists of two solar panels supplying 1500W each, a silver cadmium battery storage section, and a suitable power conditioning section.

Solar arrays are a highly reliable source of power as demonstrated by the success of solar power systems to date. Design considerations in the use of solar arrays must take into consideration such problems as packaging, deployment, and interaction with other spacecraft subsystems. A key problem is maintaining orientation of the solar array toward the sun.

Primary factors which affect array output are the change in solar intensity and the resultant change in panel temperature. A high temperature results in lower solar cell efficiency. Techniques which may be used to control array temperature include control of emissivity of the surfaces, efficient structure design, variation in the ratio of cell coverage to overall panel area, and variation in the angle between the sun-vehicle axis and panel.

The oriented array has size and weight advantages, but there are some critical areas that exist in the integration with the spacecraft. One area is that of the orientation mechanism; bearings would be needed to allow rotation of the array. Bearings must be able to resist the thermal environment and radiation of the flight environment without a change in their critical dimensions or the release of any condensing gases. Another area where a tradeoff must be performed is in the use of slip rings or folded cables for power transfer.

The basic array structure consists of a substrate panel supported by a skeletal frame. The substrate supports the solar cells, wiring, and other equipment and should be strong enough to support its own weight during launch. The substrate and frame structure have proven reliability in a space environment and allow a low-temperature operation through a good thermal design. Low operating temperatures improve the cell efficiency and increase the power level.

The solar cell panel problems of structure, launch integrity, and deployment are relatively straight forward design problems which do not affect system feasibility. Advanced development will include the construction of prototype panels for structural, launch environment, and thermal cycling evaluations.

Thermal control coatings on the panels must be resistant to the ultraviolet radiation of the flight environment so that no significant change will occur in the design values of absorbence and emittance.

Design of the solar arrays and spacecraft should take into consideration the following interface problems:

a. Exhaust impingement from the RCS

b. Experiment clearance

c. Electrical, magnetic, and radio frequency interference limits

d. Space envelope interface for both stowage and deployment between the arrays, spacecraft booster, and shroud

Manufacturing feasibility must be directly proportional to the produceability of design. The following factors must be considered:

a. Configuration and size must be compatible with normal tooling practices.

b. Solar panel assemblies and solar cell installation require use of bonding materials. The thickness and area of application of these materials must be accurately controlled.

c. Configuration of the complete array must be such that fixturing for the positioning and holding of components and subassemblies can be accomplished to provide support during array assembly.

d. Manufacturing must be able to repair or replace any component of the solar array at any step during the fabrication sequence.

31.3.1.2.4.3.1 Test

The test and checkout activity as regards development and qualification of the solar array shall essentially be finished upon completion of solar array installations on the spacecraft.

The test program will be conducted at the factory site and also at the high altitudes location (Table Mountain) to evaluate solar cell performance in response to stimulation by the sun's rays.

Normal test event sequences will be:

a. Inspection

b. Factory stimulation of solar cells

c. Remote site testing of solar cells

d. Ground ambient tests

e. Test analysis

f. Vacuum chamber tests

31.3.1.2.4.3.1.1 Design Criteria Test

The design criteria test will be performed to establish specific design characteristics to be included in the component and subsystems design.

31.3.1.2.4.3.1.2 Design Development Tests

The object of these tests will be to functionally prove the feasibility of proposed materials, processes, and design.

31.3.1.2.4.3.1.3 Qualification Tests

The qualification tests of components and subsystems will be performed to demonstrate satisfactory functional capability under stringent mission conditions.

31.3.1.2.4.3.1.4 Flight Acceptance Tests

These tests will demonstrate both that satisfactory functional capability has been attained and that the mission article has been fabricated to, and functions per, design requirements.

31.3.1.2.5 Communications and Data Handling Subsystem

31.3.1.2.5.1 General

The communications and data handling subsystem encompasses telemetry, data processing, and displays and controls. Communication during launch, earth orbit, transfer orbit, transearth coast, and reentry phases will use only Command Service Module (CSM) equipment. During these early phases of flight, OTAES telemetry requirements will be limited to monitoring critical vibration and temperature points in the spacecraft. The instrumentation and communications subsystems will use an Optical Technology Test and Operations Station (OTTOS), now being developed, as well as equipment and facilities established for the Apollo program.

The mission support activity of the OTAES communications and data handling subsystems will begin when the CSM and OTAES spacecraft are docked and the experiments are set up. Briefly, spacecraft equipment will sense, process, store, and transmit experimental, life support, navigational, and voice data via an Apollo Unified S-Band (AUSB) downlink; the equipment will receive, decode, and integrate updata signals and commands from the ground stations; and crew members will be connected by a VHF voice link.

31.3.1.2.5.2 Design

The overall data management subsystem includes ground based facilities as well as spaceborne equipment, but a design goal has been to use existing ground facilities with minimal changes. The baseline approach has been to assure mission success by designing a spacecraft subsystem having the qualities of flexibility and redundancy. Flexibility will allow experimenter both to prearrange equipment for optimum experimental procedures and to make rapid changes in experimental or data management modes during the course of an experiment.

31.3.1.2.5.2.1 Telemetry

Telemetry and ground communications will utilize the AUSB system as the prime space-to-ground and ground-to-space communications link. A VHF system will be used for communications between the CSM, the OTAES vehicle, and astronauts performing EVA. In case of AUSB malfunction, a VHF link will function as backup for the space-to-OTTOS communications link.

The choice of the AUSB system as the prime communications link leaves one problem unsolved. The 0.05 million bits per second (mb/s) capability of AUSB is inadequate to handle the data rate of 10^8 mb/s required by some of the experimental groups. Rather than develop an entirely new advanced communications system, however, the data rate will be reduced by preprocessing and compressing data prior to introduction into the downlink multiplexer.

Most of the telemetry equipment will be used as designed for the Apollo mission. One of the few changes will be the substitution of two erectable S-band omni antennae for the single steerable antenna used on the LM. The only major addition will be an optical transceiver and related multiplexer/demultiplexer used in a short communications link between the 3-meter telescope and the spacecraft. This link will enable experimental data and control signals to be transmitted across the paramagnetic suspension without subjecting the suspension to the deleterious effects of radio frequency interference. The equipment used in this link will occupy about 2000 cubic inches of space and weigh approximately 70 pounds.

The AUSB terminal buffers, Apollo TM recorder, and Apollo TV camera will be used with only minor changes. The only major advance will be to increase the capability of the low-power, high bit-rate multiplexer in the AUSB terminal buffers. Approximate volumes and weights of the components are 850 cubic inches and 30 pounds for the buffers, 150 cubic inches and 15 pounds for the TM recorder, and 100 cubic inches and 5 pounds for the TV camera.

The LM equipment to be used will be space qualified prior to hardware stages of OTAES, but it will be necessary to subject the breadboard optical transceiver and related multiplexer and demultiplexer to severe environmental tests such as those specified in MIL-STD-810A. After development of the components, it will be necessary to subject the flight article to environmental tests in a simulated flight mounting for a period equal to the duration of powered flight.

For long-range laser communications under adverse weather conditions it will be necessary to study atmospheric conditions and accurately assess their effect on the laser beam path. For the OTAES laser experiments, the meteorology study will use radio theodolites carried by balloons along the laser beam path. Balloons will give better atmosphere stay times for the theodolites than will aircraft, sounding rockets, or parachutes. Signals received and evaluated by ground weather stations and OTTOS will be relayed to the satellite via the AUSB uplink. Spacecraft subsystems may manually or automatically correct laser beam deviations on the basis of input/output signal ratios. A correlation linking atmospheric phenomena with deviations in optical link signal will be accomplished at this time so that more advanced laser beam tracking systems may be developed for future flights.

31.3.1.2.5.2.2 Data Processing

The onboard computer will be the central element of the spacecraft communications and data handling subsystem. The computer regularly samples experimental data, generates displays from the data, processes commands controlling sampling and displays, and monitors test points for malfunctions. Approximately 1200 experimental signals and about 700 flight support and life support signals are processed by the computer for the AUSB downlink. The experimenter will have the option of transmitting data in real-time, of storing data for later transmission, of modifying data rates, or of deleting any given data input entirely. The computer will also receive and process AUSB commands and voice signals at the same time it monitors communication equipment for malfunctions.

Processing of experimental data signals may include data compression prior to introduction of signals into the downlink multiplexer. This reduction in data rate is necessary for raw experimental signal groups operating at rates in excess of AUSB capability. Functional flexibility of the subsystem will allow the data bit rate to be fully controlled by the experimenter in either an automatic or manual mode.

Components in the data processing subsystem will utilize approximately 50 per cent of the existing LM equipment. Advances are necessary in the areas of analog-to-digital converter technology, sensor conditioner components, and of improving the available bandwidth for the video recorder. New additions for OTAES spacecraft will be redundant modules for the 4 Pi computer and the data compression component. Volumes of these components are 900 cubic inches and 25 pounds for the data compression unit and 3200 cubic inches and 145 pounds for the 4 Pi computer. These systems will have to be subjected to launch environment and space conditions during development and qualification. Other major component packages are the sensor conditioners (4330 cubic inches and 150 pounds) and the video recorder with auxiliary equipment, magnetic tapes, and reel storage (6600 cubic inches and 300 pounds).

31.3.1.2.6 Structure Subsystem

31.3.1.2.6.1 Modifications

The structural subsystem for spacecraft configuration No. 1, utilizes a modified LM ascent stage structure from which the ascent engine has been removed. A square platform composed of beams and skins, with four corner supports for the LM shroud, will be attached to the ascent stage using the same attachment points as a standard LM descent stage. Four telescope wells and one experiment well will be mounted below the platform. The platform thus provides a means of support for both the LM ascent stage and the experiment hardware. To allow manned accessibility to experiment equipment it will be necessary to add a hatch at the ascent engine well for egress to the experiments. A 0.81-meter-diameter tunnel attaches to the ascent stage at the new hatch to provide a pressurized access compartment so that a man can move to the experiment hardware. This compartment will also provide an additional work area in the vicinity of the experiments for shirtsleeve maintenance and monitoring, and will function as an airlock to conserve oxygen when the experimenters gain access to the telescopes.

31.3.1.2.6.2 Telescopes

The telescope well is a cylindrical housing for the telescope, the purpose of which is to act as a thermal and protective barrier against the dangers of a space environment. The telescope is sensitive to thermal gradients so the well must be designed to minimize those gradients. The following is a description of the telescope wells and experiment supports that must be developed as an integral part of the spacecraft structure. The mirror experiment well will be a cylinder 1.52 meters in diameter and 4.06 meters long with doors on each end. The experiments are arranged to divide the shell at the midlength. Two 0.81-meter-diameter parts in the shell adjacent to the manned compartment are required for manned access to allow for maintenance or adjustments. The shell must be designed so that it is structurally capable of transmitting equipment weights to the support points. The 1.0 and 0.3-meter laser experiment well consists of a pair of cylindrical shells which surround and provide mounting and protection for the laser, optics, and telescope. The main cylinder is 1.42 meters in diameter and 3.50 meters in length, with a strap-on cylinder 0.76 meter by 1.98 meters. There is a hatch on one end only. A common gimbal attaches to the shell at midposition. A gimbal control system is required and a caging system is necessary. This requires a 1.14-meter gimbal ring with bearings, torques, data bridge, angle sensor, and caging device to allow a ± 3° of pointing on two axes. The gimbal attaches to the telescope on one axis and to the well on the other axis. Another telescope well is required to mount and protect the gimbaled 0.3-meter laser telescope and provide structural attachment to the platform. In addition to these wells, a structure is required to provide means for supporting magnets, springs, and cage devices around the fine-guidance telescope suspension system. This structure consists of a cylinder 1.70 meters in diameter and 1.62 meters long, and is attached to the platform by support brackets.

31.3.1.2.6.3 Design

In the design of the telescope wells a major tradeoff being resolved is between the structural and thermal requirements. Thermal problems dictate that the insulation be attached to or sandwiched within the wall of the well. Material selection for the structure is also affected by thermal considerations. The telescope wells have hatches on their open ends. The hatches must be opened and closed periodically during the mission; therefore, the hatch mechanisms must be operable in a space environment. The effect of cold welding of lubricants caused by vacuum and radiation will be a prime consideration in the preliminary design.

Of major concern in the design and development of the spacecraft structure is the space environment that will be encountered. This will consist of radiation, vacuum, temperature, and micrometeoroid environments. The vacuum environment of space does not pose any major problems to structural design. Surface coatings will be selected to withstand this environment. Radiation shielding becomes very significant for spacecraft in synchronous orbit. An assessment of radiation levels inside the spacecraft will be accomplished and the analysis will be incorporated into the design criteria. One of the more important parameters to be considered is the effect of a micrometeoroid environment on the spacecraft. Hypervelocity impacts by micrometeoroids can damage the spacecraft in various ways. Although the ascent stage has been previously qualified for the space environment, the present shields will be replaced with heavier gage shielding to withstand a 45-day manned mission and a 360-day total mission.

Another consideration that must be made in the spacecraft design is the comprehensive integration of thermal analysis. Projected thermal gradients resulting from preliminary thermal analysis are recognized, and structural hull skins and the interior structure will be developed within these constraints.

31.3.1.2.6.4 Test Requirements

The modified LM ascent stage and the additional structure requires development and qualification testing to measure the performance and design adequacy of the complete structure. The LM ascent stage has been previously qualified for Apollo missions and it is felt that the modifications to this stage can be qualified by evaluation and analysis, plus a proof pressure test. The platform structure, tunnel, experiment access compartment, telescope wells and other structural components will require the usual development and qualification testing normal for manned space flight. The following tests are an example of what will be performed.

a. Static structural tests

b. Dynamics tests

c. Thermal vacuum tests

d. Flight acceptance tests (See Preliminary Test Plan)

31.3.1.2.6.4.1 Static Structural Tests

The static structural test is required to determine structural integrity under maximum flight loading conditions. A structural test unit will be fabricated and will be equipped with appropriately located strain gages and dial indicators to measure stress and deflection under load. In order to determine the ultimate burst pressure, safety factors, failure characteristics, and design limitations, this structural unit will be tested to destruction.

31.3.1.2.6.4.2 Dynamics Test

The purpose of dynamics testing is to conduct ground vibration surveys to determine body bending and torsional dynamic behavior. A prototype will be constructed for use as test hardware. This hardware will be supported in the dynamics test structure and excited by electrodynamic shakers. Dynamic response of the test hardware will be recorded by a network of accelerometers and rate gyros mounted throughout the structure. Tests will include excitation in the lateral, torsional, and longitudinal planes. Dynamics testing of the ascent stage itself will not be necessary; previous test results can be used to establish the vibrational modes.

31.3.1.2.6.4.3 Thermal Vacuum Tests

To ensure satisfactory operation in the simulated vacuum of space, the prototype structure will be installed in a thermal vacuum chamber. The structure will be tested for degradation of materials caused by the effects of high vacuum, solar radiation, hot and/or cold spots in equipment such as well doors and gimbals, and the effects of high vacuum on moving mechanical systems.

31.3.1.2.6.5 Solar Cell Mechanisms

The solar cell mechanisms operating in a hard vacuum for the life of the spacecraft will receive special attention. Preliminary design of the mechanisms will include an extensive investigation of solar cell system motion and clearances. Preliminary sizing will be made so that the package size can be verified and its effect on surrounding equipment and spacecraft strength and weight can be accurately determined. Preliminary analysis will be performed on the deflection/rigidity, reliability, and strength of the system. The results will strongly influence the mechanism design.

Design verification and qualification tests must be performed on the array structure, the deployment system, and the mechanism required for continuous solar panel orientation. A prototype system will be constructed for thermal vacuum, shock, and vibration tests. The prototype will also be used for prelininary deflection checkout, and for the verification of stowing and extending concepts. Components will be further tested for degradation under prolonged hard vacuum exposure.

31.3.1.2.7 Control and Display Subsystem

31.3.1.2.7.1 General

The control and display subsystem provides the astronaut with information for monitoring, control, and operation of the spacecraft subsystems. A prime consideration in the preliminary design analysis, has been to utilize, wherever possible, existing lunar module control and display instrumentation, mounting structures, and electrical harness and wiring. However, many modifications and additions will be necessary to convert the LM ascent stage controls and displays to meet OTAES requirements. These changes will reflect the different requirements of the individual subsystems and the needs of the experiments. Present types of components such as meters, toggle switches, etc. will be used wherever possible.

31.3.1.2.7.2 Design

The preliminary design effort will involve monitoring the status of all subsystem designs including the experimental program. Layouts will be made to ensure that control and display requirements are compatible with the interior of the spacecraft, use by the crew in a shirtsleeve environment, vented suit and pressurized suit conditions, volumetric and panel availability, and maintainability.

New panels that will be required are:

a. 1.0-meter telescope panel provides telescope power control and readout, fine beam deflection information, tracking error, and boresight error.

b. 0.3-meter telescope panel is almost identical to the panel for the 1.0-meter telescope.

c. Star trackers and sun sensors panel gives digital and projection screen attitude readouts from the star trackers' and sun sensors' inputs. Mode switches are provided for selection between the

No. 1 Star Tracker, No. 2 Star Tracker, Wide-Angle Sun Sensors, and Narrow-Angle Sun Sensors.

d. Thin mirror figure experiments panel includes a cathode ray tube (crt) circuit which presents an interferogram of the thin mirror surface during experimental conditions. Development and testing must take place in order to qualify the crt to the high-intensity sound, vibration, acceleration, and shock to be experienced during the powered portion of the flight.

e. Laser power supply panel includes current controls and readouts to five independent lasers, has laser frequency stabilization controls and indicators, and has on-off switches to the laser transmitters, receivers, and detectors. Power failure indicators are also included.

f. Fine guidance and suspension control panel. The fine guidance portion of this panel allows calibration of the intermediate and fine guidance sensors, indicates sensor errors, and allows star lock-on. The suspension control portion of the panel has controls for suspension mode, suspension, pitch gimbal, and yaw gimbal rings, and indicates telescope acceleration, translation, and gimbal angle.

Establishing design criteria requires the implementation of control and display devices capable of meeting anticipated system operational and human factor needs. At present a preliminary soft mockup has been developed for the purpose of determining the extent of panel surface and volume availability, accessibility, and other human factors considerations.

From the preliminary mockup efforts, it has been determined that panel availability appears to be sufficient for presently anticipated control and display requirements. Full scale static and dynamic prototypes of the consoles will be fabricated for use during development and qualification testing.

31.3.1.2.7.3 Test

Development testing will evaluate form, fit, and function, and ensure the adequacy of the preliminary design. A function generator or other input will be required to operate dynamic displays and to execute controls in order to verify normal, backup, and emergency modes, and to evaluate astronaut test subject performance.

Using the prototypes previously identified, all components and assemblies will be subjected to vibration, shock, temperature, vacuum, outgassing, and other applicable environmental tests. These tests will demonstrate that the subsystem functions according to design specification and that a high level of confidence can be placed in the operation of the hardware.

31.3.1.2.8 Crew Provisions Subsystem

The crew provisions subsystem includes all equipment and provisions necessary for crew sustenance, protection, survival, and operational effectiveness. Present consideration has been centered primarily around identifying body stabilization and anchoring supports and establishing a loose-item equipment list. Efforts to be expended in subsequent phases can be divided into the following categories: 1) system requirements analysis, 2) system function definition, and 3) design support.

31.3.1.2.8.1 System Requirements Analysis

This includes those things which the system must be able to do and the limits within which they must be accomplished. The analysis involves the study of mission objectives, performance requirements, and system constraints.

31.3.1.2.8.2 System Definition

This involves identifying and describing system functions and includes design implementation and the identification and definition of training requirements.

31.3.1.2.8.3 Design Support

Once the system functions are identified, design criteria will be developed which will encompass both hardware and human factors considerations. Throughout the design phase a continuous program of design evaluation will be conducted which will contribute to tradeoff decisions.

31.3.1.2.9 Thermal Control Subsystem

Requirements for active thermal control of the spacecraft are considered part of the environmental control subsystem (ECS). Refer to the ECS for information about spacecraft thermal control (paragraph 31.3.1.2.2).

31.3.1.2.10 Costs and Schedules

The costs and schedules shown in this plan are preliminary gross estimates only. Projected spacecraft subsystem DDT&E schedules are shown in figure 31.3.1.2.10-1. These schedules show that it will take approximately 36 months from authority to proceed, to complete subsystem development and prototype qualification. Figure 31.3.1.2.10-2 shows total DDT&E for a single article and also a production schedule for all the articles to be built. The Acceptance Testing activity is not included in this schedule.

The total cost for the baseline OTAES spacecraft (excluding experiments) DDT&E effort is presented in table 31.3.1.2.10-1 and is estimated at $54,200,000. This includes development, assembly, and testing of the prototype article and structural unit. Table 31.3.1.2.10-1 also shows the DDT&E cost broken down by subsystem and includes subsystem installation,

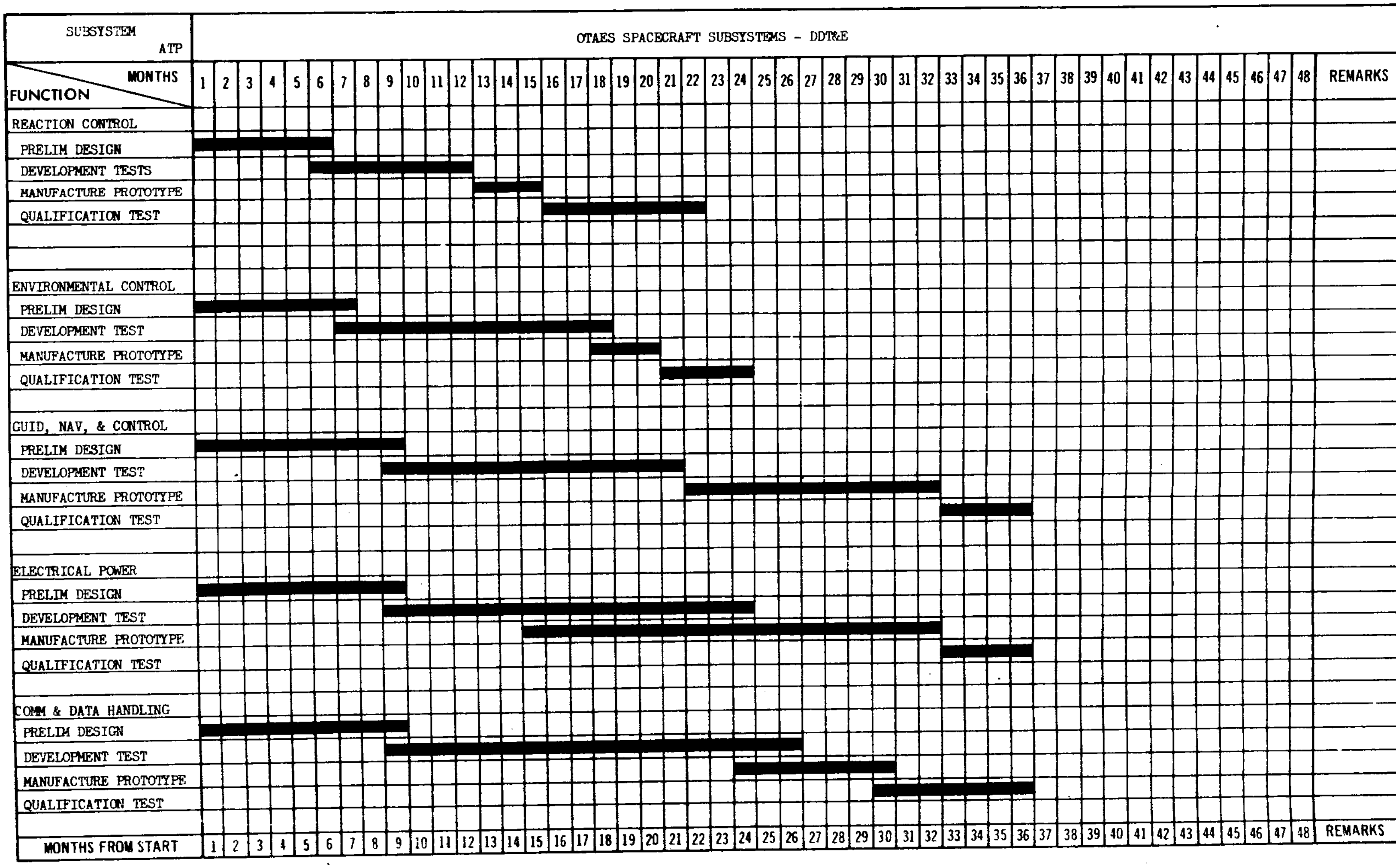

Figure 31.3.1.2.10-1. Spacecraft Subsystems DDT & E Schedule

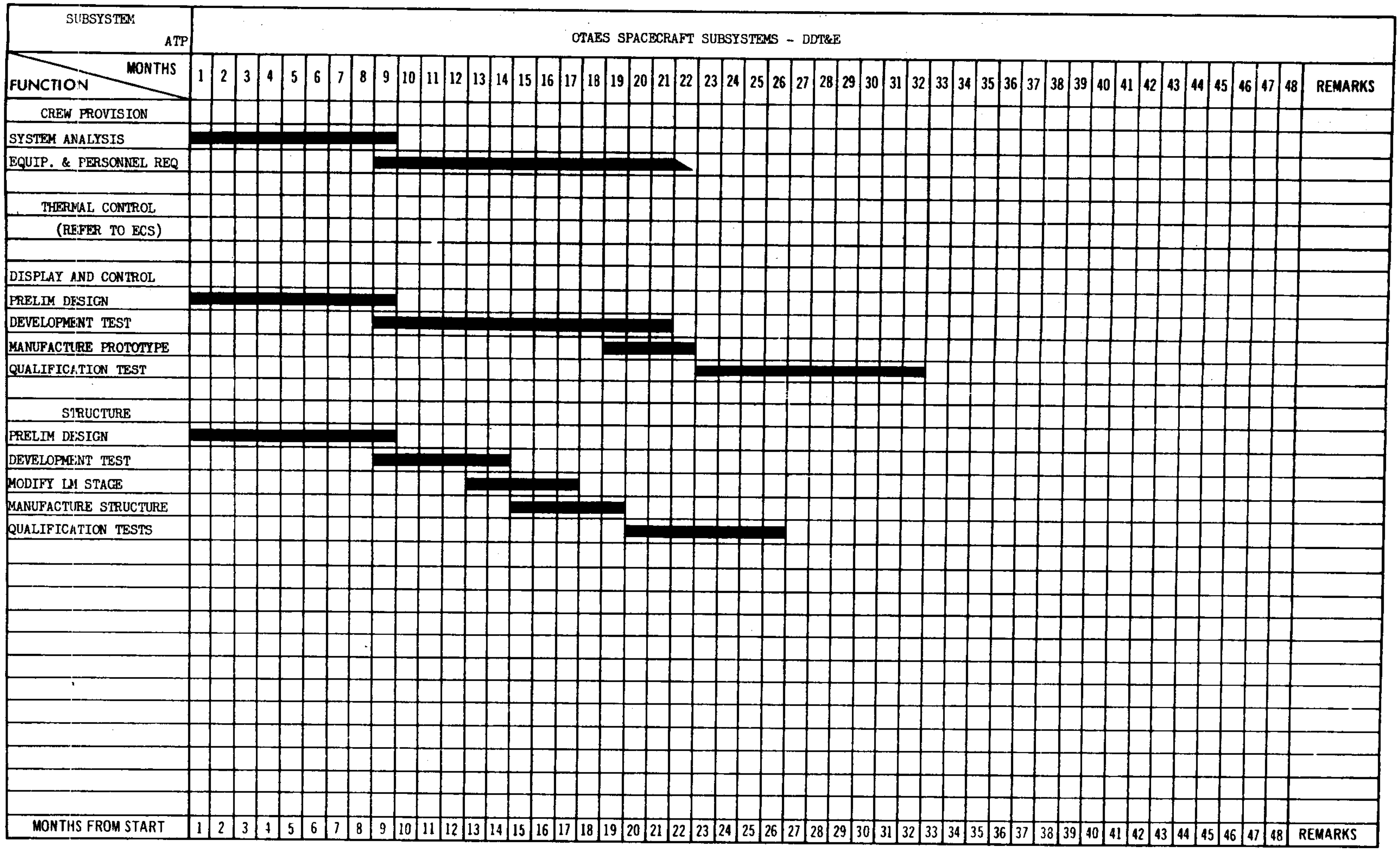

Figure 31.3.1.2.10-1. Spacecraft Subsystems DDT & E Schedule (Continued)

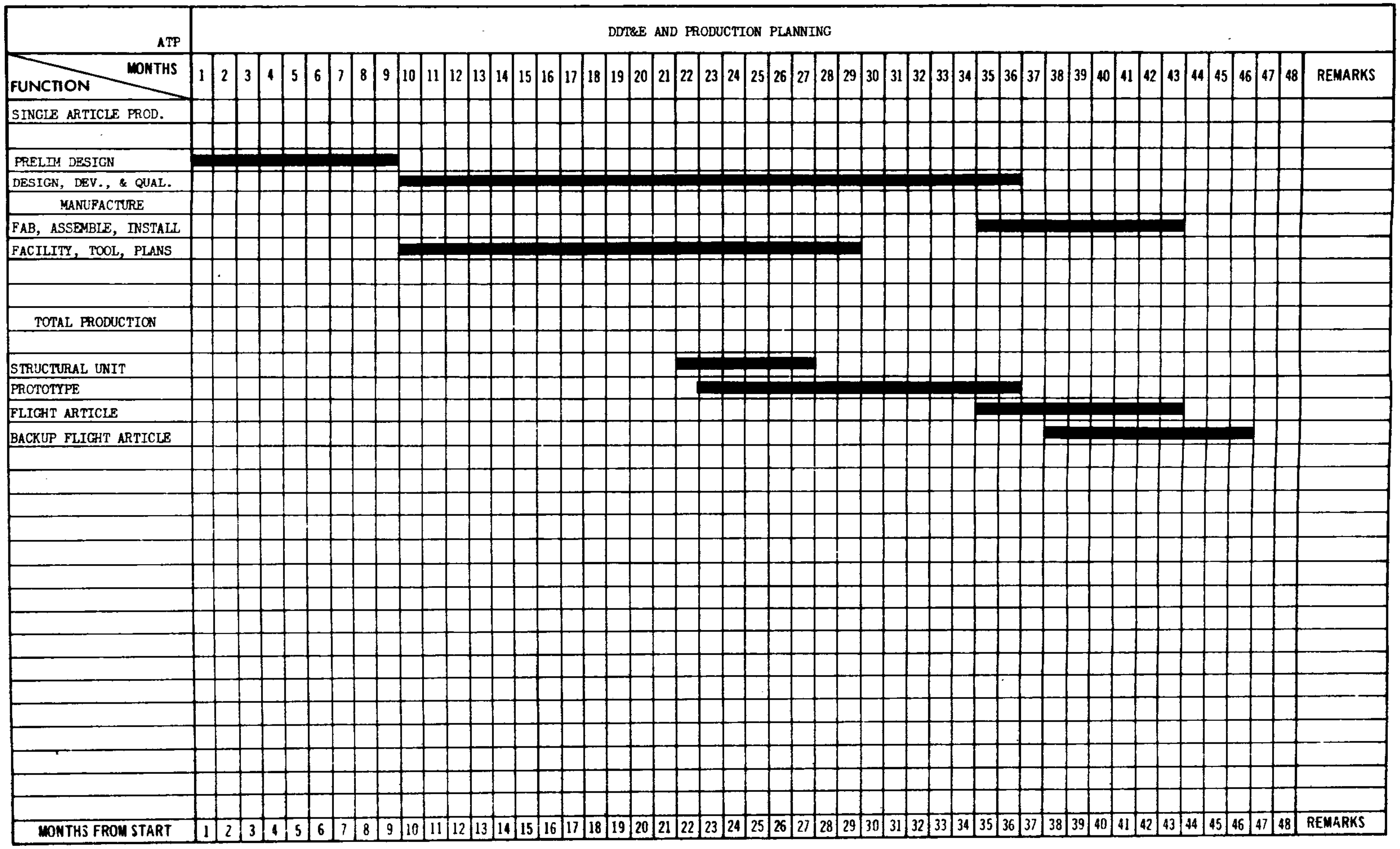

Figure 31.3.1.2.10-2. Spacecraft DDT & E and Production Planning Schedule

integration, and qualification testing costs. These estimated costs are shown again in figures 31.3.1.2.10-3 and 31.3.1.2.10-4 to provide a subsystem comparison and dollar distribution picture.

TABLE 31.3.1.2.10-1

DESIGN, DEVELOPMENT, TEST AND EVALUATION COSTS

Subsystems	Cost
Reaction Control	$3,000,000
Environmental Control	4,000,000
Comm. & Data Handling	3,000,000
Guid, Nav, & Control	12,500,000
Electrical Power	6,000,000
Structure	11,000,000
Display & Control	5,500,000
Crew Provisions	700,000
Sub-total	$45,700,000
Subsystem Installation and Integration	6,000,000
Qualification Testing	2,500,000
Total	$54,200,000

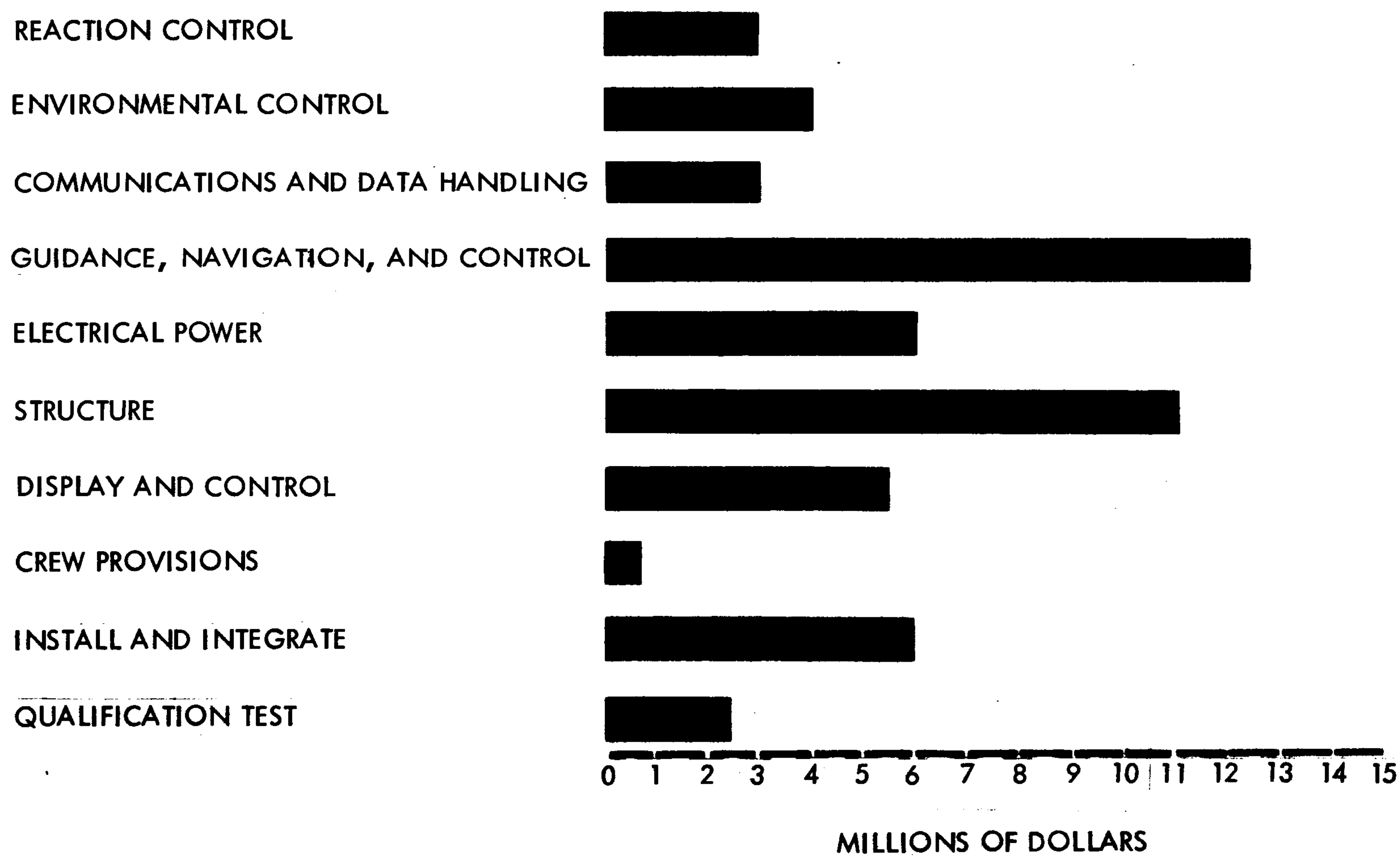

Figure 31.3.1.2.10-3. Subsystem Cost Comparison

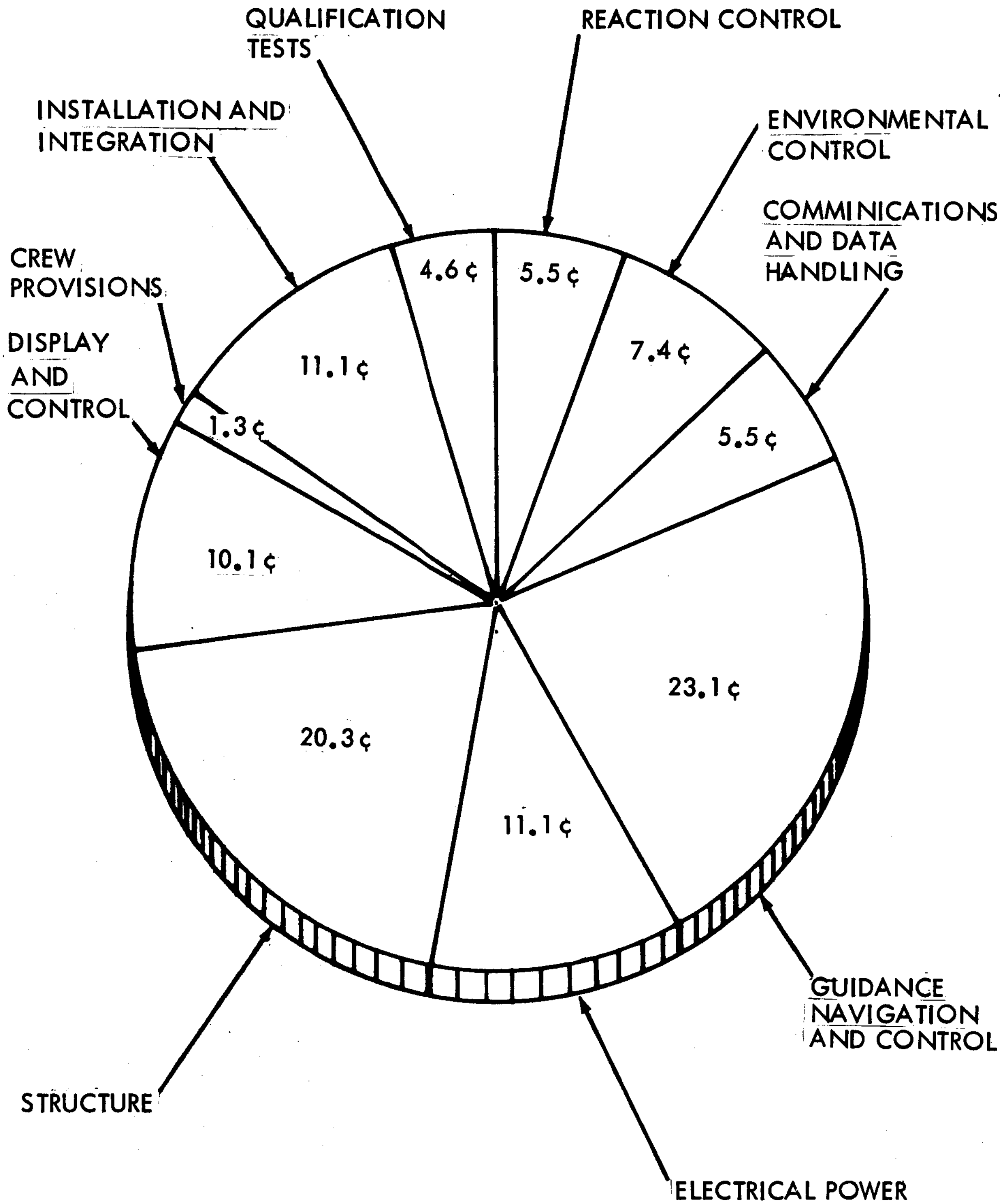

Figure 31.3.1.2.10-4. Spacecraft DDT & E Dollar

31.3.2 Preliminary Manufacturing Plan

31.3.2.1 Introduction

The basic approach to manufacturing the OTAES spacecraft is to purchase a LM (Lunar Module) ascent stage, less the propulsion section, and modify it to OTAES configuration at the Michoud Assembly Facility in New Orleans.

Structural modifications involve attaching a platform under the ascent stage. Below the platform, there will be an access compartment, three laser telescope wells, a primary mirror test well, and a fine guidance and isolation experiment well. A tunnel will be constructed from the ascent stage to the pressurized access compartment in the space formerly occupied by the ascent stage engine. Outer shields of the LM ascent stage will be replaced with heavier gage shields to afford meteroid protection for a 45-day manned mission and a 360-day total mission.

The spacecraft will be constructed in sections and then assembled using standard tooling concepts, holding fixture type devices, and automatic welding equipment.

Preliminary planning calls for one flight article, one back-up flight article, one prototype article, and one structural test article. The structural test article will consist of the platform, access compartment, and experiment wells only. See Manufacturing Schedule figure 31.3.2.1-1.

31.3.2.2 Manufacturing Philosophy

Manufacture of mechanical and electronic components will be completed in the Prime Contractor's machine shop or in the Subcontractor's plants, as the particular requirements dictate.

Selection and purchase of components will involve review of hardware availability to meet specification requirements, establishing requests for quotation (RFQ) with competent vendors, reviewing, vendor capability, engineering review of component requirements with vendors, and placing purchase orders for necessary parts. After parts have been ordered, liaison with suppliers will be necessary to assure technical and schedule performance.

A detailed manufacturing plan, closely integrated with the subsystem development programs, is required. The manufacturing organization should define producibility methods during the design phase. Mockups should be available not only to aid the designers but also to help the manufacturing personnel understand the mounting of components or subsystems, checkout procedures, and assembly procedures. The manufacturing plan should be initiated as soon as the vehicle configuration is defined. Continual revision of the plan is necessary as the design, through drawing releases, becomes firm. Integration of the basic fabrication, procurement, and assembly tasks with facilities, tooling, handling equipment, and checkout or inspection requirements will also require the manufacturing plan to be updated at regular intervals. The manufacturing organization should collaborate with the design organization during

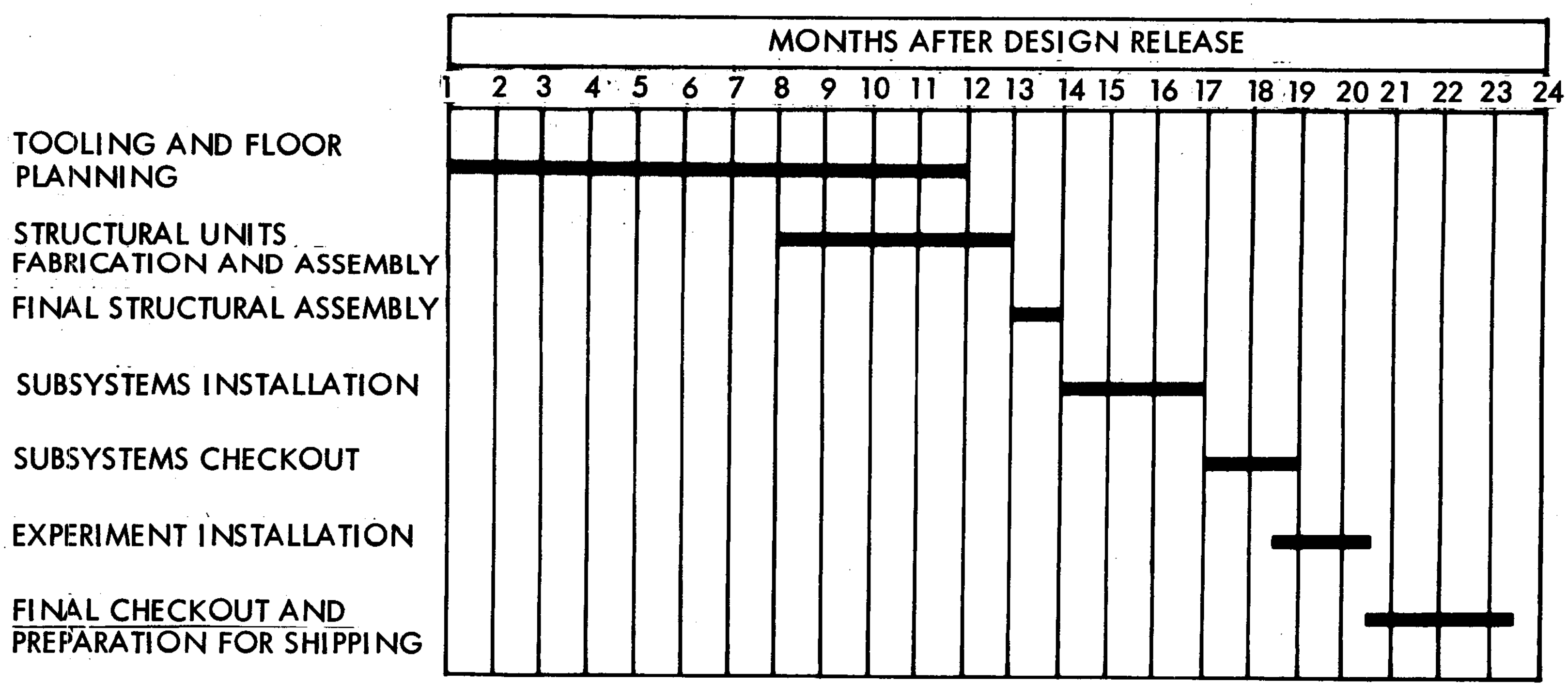

Figure 31.3.2.1-1. Spacecraft Manufacturing Schedule

the development and prototype fabrication phases of the program. Much can be learned about handling techniques, component and subsystem fabrication, and assembly that will be reflected in the manufacture of systems test and flight vehicles during the development test programs.

Milestone events that affect manufacturing efforts must be clearly defined. An example is the release of engineering drawings. These must be reviewed with respect to allowing sufficient time for processing, tool design and fabrication, procurement and/or fabrication cycles, and in-process and final inspection times.

Quality assurance test procedures or inspection requirements must be available at the proper time to allow an uninterrupted manufacturing flow.

Problem areas must be anticipated in time to allow either a corrective action or an alternate approach to be established. By knowing current status of the task, and comparing it to both the manufacturing plan and the program plan, problems can be analyzed with respect to schedules and costs.

As design configurations become available, manufacturing planning becomes more complete, and task and subtask effort definitions become more detailed. Until the first test vehicle is finally completed and checked out, the manufacturing plan will be a working document under constant revision.

31.3.2.3 Sequence of Operations

After structural units have been fabricated and tested, assembly procedures will begin with the structural platform. Then the telescope wells will be installed above the platform. Concurrently, some of the subsystems will be mounted in the LM ascent stage. Next, the structural platform (with experiment wells installed) will be inverted onto a set of assembly jacks in a clean room, and the LM ascent stage will be installed on top of it. The remainder of the subsystems will be installed in the ascent stage. Pressure tests of the environmental control subsystem (ECS) controlled areas will be conducted. Finally, the experiments will be installed. After completion of assembly procedures, final checkout will be accomplished and the spacecraft will be prepared for shipping (see figure 31.3.2.3-1).

The anticipated sequence for installing telescopes and wells is as follows:

a. Install wells to platform.

b. Install gimbal rings and support brackets to wells.

c. Install telescopes to gimbal ring and support brackets.

d. Install counter weights.

e. Install counter weights cover.

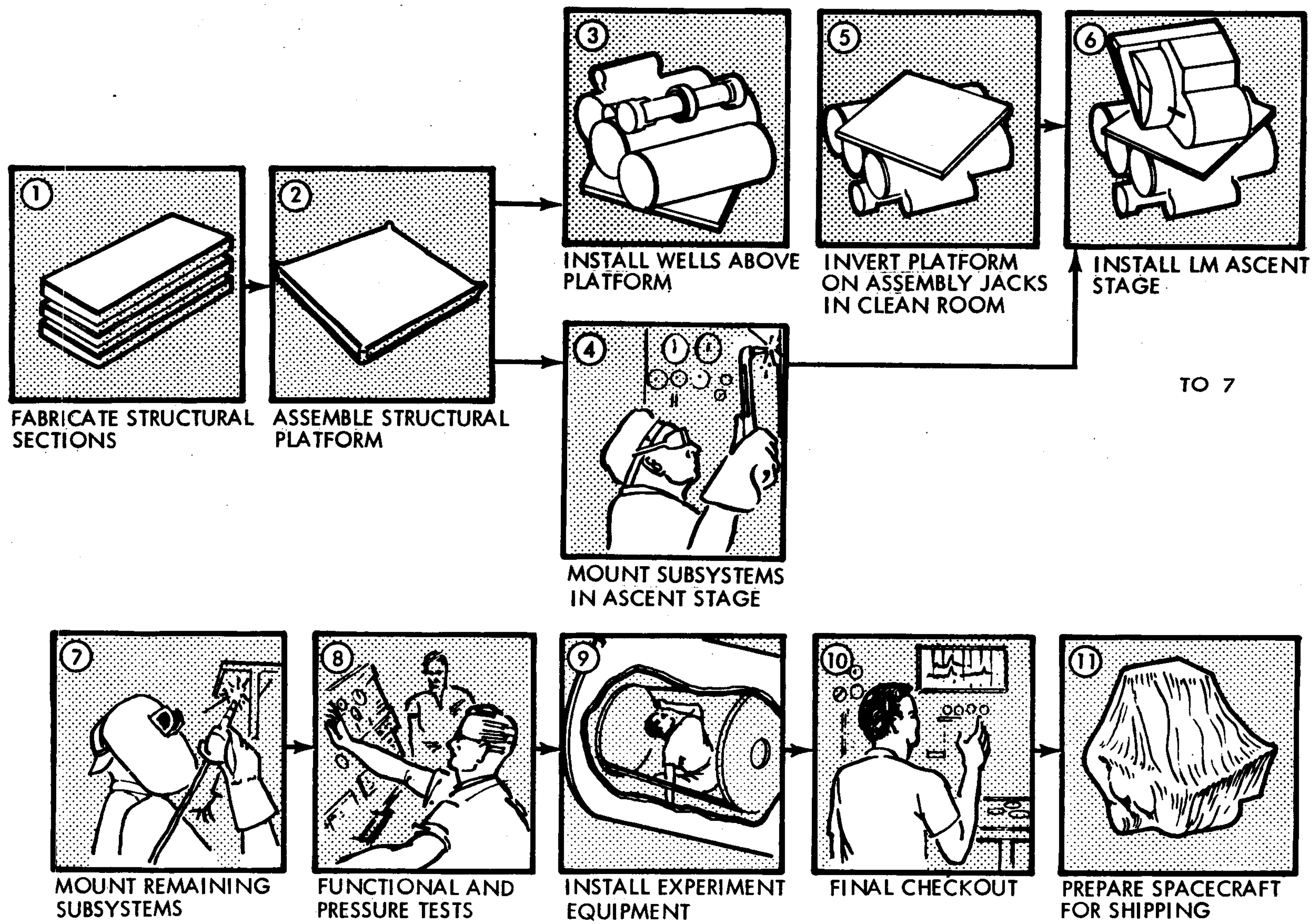

Figure 31.3.2.3-1. Sequence of Operations

31.3.2.4 Tooling Concepts

Tooling and fixtures that will be used to fabricate the structure will be inspected and certified as a medium of inspection whenever possible. Inspection of all fixtures will be accomplished in a building block manner. Interface production tooling will be inspected and certified and will be periodically coordinated to the master tool which will control the interface characteristics.

All critical dimensions affecting reliability, dependability, and/or fit-up will be inspected to an approved quality level using standard measuring equipment, special gages, templates, or certified tooling as required. Characteristics to be inspected will include but not necessarily be limited to the following: Overall length and width, hole locations, hole sizes, material thickness, threads, angles, flatness, surface finish, etc.

31.3.2.5 Quality Control

The quality control program will be designed to assure a high level of quality during all phases of production from development to shipping of the subsystems and components. All hardware fabricated within the Contractor's plant or at any other source will be controlled by documented inspection and test instructions at all points necessary to assure conformance to design requirements. Quality control will effectively control purchased materials, subcontracted work, and in-house fabrication and assembly by means of established inspection and documentation requirements for all purchase orders and manufacturing orders.

To implement this control, the quality control effort will cover three basic areas of operation: planning, inspection, and measurements.

a. Quality control planning personnel will be responsible for reviewing the requirements of the contract to make provisions for the special controls, processes, test equipment, fixtures, tooling, and skills required for the program. They will also be responsible for the correlation of inspection and test results with manufacturing methods and processes, and for providing appropriate review and action to assure compatibility of manufacturing, inspection, testing, and documentation. They will be responsible for initiating corrective action to update testing techniques, instrumentation, documentation, and quality instructions and procedures. Quality control planners will prepare and issue inspection, test, and documentation procedures and instructions for specific nonrecurring tasks that arise during the implementation of the quality program, and which are not covered specifically by the existing procedures and instructions: for example, retesting after a rework or replacement operation.

b. Inspection personnel will be responsible for performing inspection and test operations specified in the various work instructions, such as test procedures and planning procedures; and the preparation of required records, logs, and data sheets. Basically, inspection and acceptance testing will be performed in three areas: receiving inspection, in-process inspection, and acceptance tests. For further details, refer to the Preliminary Test Plan.

c. Measurements of all data relative to purchased material quality level, in-house manufactured quality level, unsatisfactory vendors, vendor surveillance actions, corrective action reports, and scrap and re-work activities will be collected, tabulated, and statistically analyzed.

31.3.2.6 Facilities

The facilities required for manufacturing the OTAES spacecraft are complex. However, utilization of existing Apollo and Saturn facilities will greatly reduce the need for new facilities. This is especially true because a great many Apollo and Saturn concepts will be applied in the manufacturing of the OTAES spacecraft. The fabrication of the spacecraft and the performance of experiment integration will be accomplished at Michoud Assembly Facility. The assembly and checkout station is shown in figure 31.3.2.6-1. For further details refer to the Preliminary Facilities Plan.

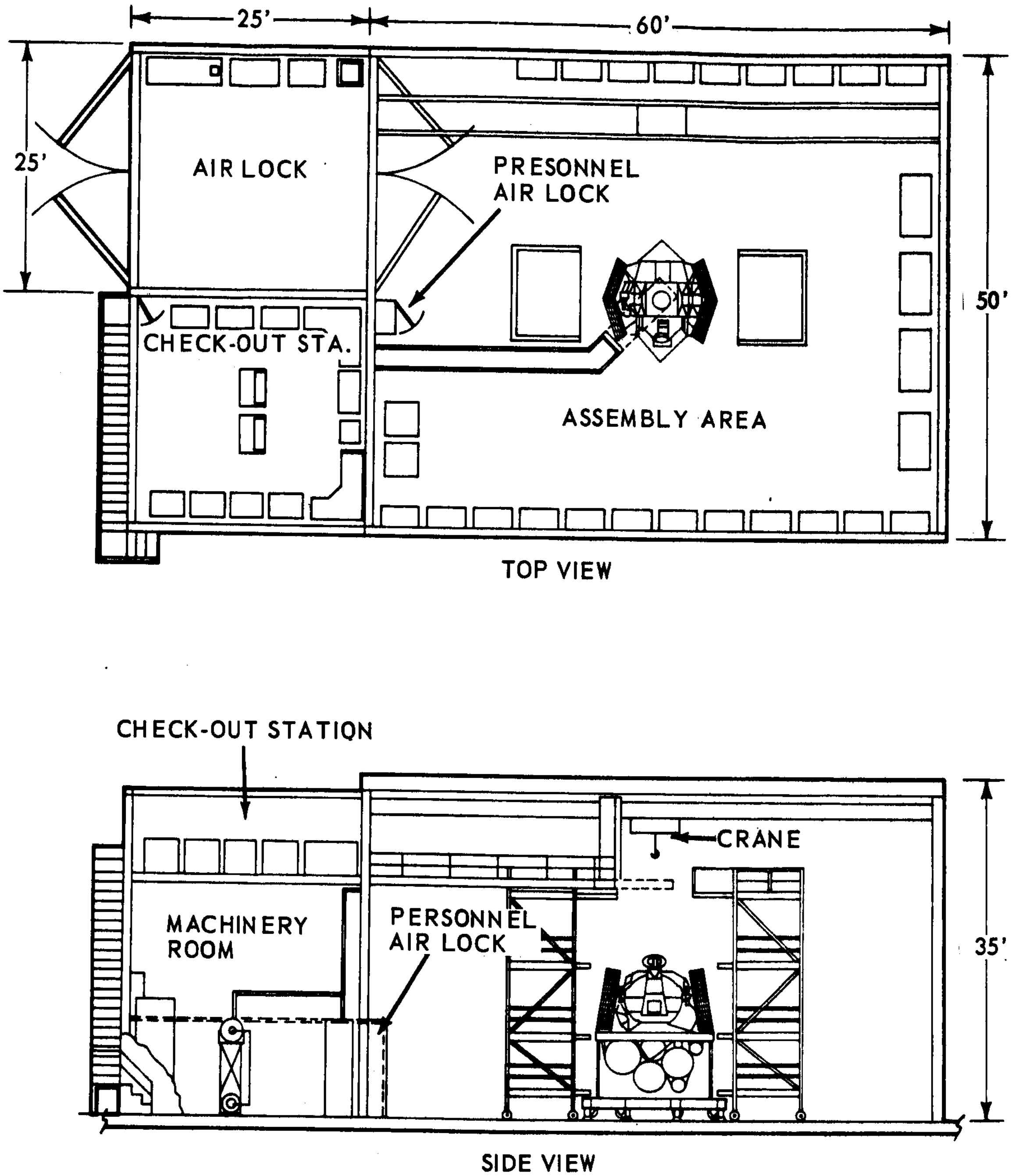

Figure 31.3.2.6-1. Spacecraft Assembly and Checkout Station

31.3.3 Preliminary Test Plan

31.3.3.1 General

The test philosophy and major test requirements necessary to develop, provide design data, and to qualify the baseline spacecraft configuration have been presented previously in the spacecraft DDT&E Plan. This test plan encompasses the testing activities that are anticipated for the production flight hardware. These activities fall under the general heading of an Acceptance Test Program. Refer to figure 31.3.3.1-1 for a diagram of the anticipated test activities.

The cost data presented in this plan are gross estimates based on the minimum requirements to perform the acceptance testing function adequately. The costs provide for one production flight unit and cover a 16-month time span from initial inprocess tests to the final acceptance of the integrated flight spacecraft. Total cost of this test activity, excluding equipment costs, is estimated to be $2.535 million.

31.3.3.2 Acceptance Test

Acceptance testing on the flight hardware begins at the component level and proceeds throughout subsystems tests and a complete integrated spacecraft checkout. These tests are performed on components, assemblies, and subsystems throughout the manufacturing processes to determine conformance to design specifications as a basis for acceptance. They consist of the functional tests, environmental tests, and physical inspection required to demonstrate that the component or subsystem was produced in accordance with specification requirements.

The major objectives of the Acceptance Test Program are as follows:

a. Assure that the end item functions and that it was manufactured in accordance with design documents, specifications, and intent.

b. Demonstrate that spacecraft performance remains within specification requirements before, during, and after environmental exposure, as required.

c. Assure functional and physical compatibility with other flight and ground support equipment.

d. Provide for acceptance of a fully operational integrated spacecraft after final assembly.

Acceptance testing is grouped into three general categories: 1) Receiving/Inspection, 2) In-Process, and 3) Flight Acceptance.

31.3.3.2.1 Receiving/Inspection

The Receiving/Inspection tests include the receiving inspection of purchase-finished assemblies, subassemblies, components, and materials. When pos-

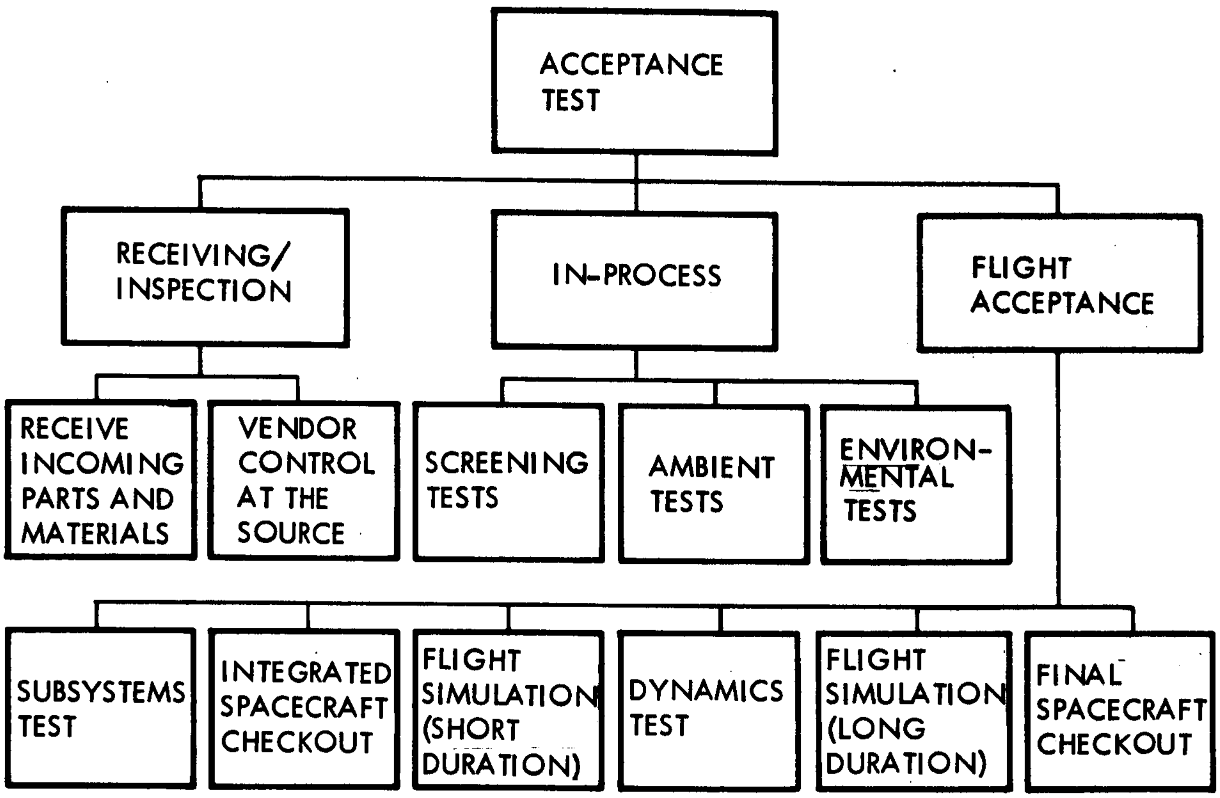

Figure 31.3.3.1-1. Functional Test Diagram

sible, only a nonfunctional test will be performed. The item will be inspected for damage and proper documentation. However, special test requirements at the point of receipt must be considered to prevent the use of equipment or material in a subsystem in such a manner that untimely discovery of anomalies would create delay. For example, calibration or preparation tests which may be required for certain assemblies prior to the integrated spacecraft assembly cycle. In some cases, receiving inspection will be performed at the supplier's facility, using their specialized test equipment. For vendor-manufactured items, whenever source acceptance is used, tests will be approved and witnessed by Prime Contractor Quality Control personnel.

31.3.3.2.2 In-Process

In-Process tests are performed at intermediate points between receiving tests and the start of the Flight Acceptance tests. These are points where further assembly would reduce the capability of a complete functional test of a specific unit. The types of testing include, bench checks, functional checks before installation or assembly of components, form and fit checks during installation, interface checks, continuity checks, and alignment checks. For in-process test planning, criteria will be established for contamination, leak/flow and pressure checks, routing of cables, harnesses and tubing, and structural integrity. Areas which may become inaccessible during the assembly cycle are emphasized.

Principal in-process test categories are: screening tests, ambient tests, and environmental tests.

a. Screening tests are those tests which employ nondestructive environmental, electrical, or mechanical stresses to identify departure from the design specifications. Screening tests will be performed when so specified in, and in accordance with, the component detail specifications.

b. Ambient tests will be conducted for the purpose of acceptance under ambient environmental conditions such as pressure, temperature, etc., normal for the test location. They are normal in-process methods of test and are performed to verify compliance with the functional requirements of the component detail specification.

c. Environmental tests will be conducted under environmental rigors other than ambient to verify the quality of the flight hardware.

Subsystem tests will be conducted with the complete subsystem to determine overall compliance with performance criteria. Specific in-process test requirements of each spacecraft subsystem must be analyzed to provide the optimum test sequence for integration of the system. Inspection stations will be appropriately located during the fabrication process to assure continuous control of quality of details, subassemblies, and assemblies, and to ensure end-item hardware compatibility with design intent. In-process test procedures will be prepared by Quality Control Engineering. The instructions (QCI/s), prepared by Quality Control, will provide all necessary work instructions for the inspection and test personnel. Stringent Quality Control surveillance, suitable for man-rating, will verify that production techniques have been adhered to.

31.3.3.2.3 Flight Acceptance Test

These tests are performed for the purpose of acceptance after final assembly and experiment integration, to ensure that modification or manufacture was accomplished in accordance with design documents, drawings, and specifications, and that the spacecraft will mate physically and functionally with other flight and ground equipment. A primary objective is to evaluate spacecraft performance throughout the range of environment and stress that it will be subjected to during the forthcoming mission. Flight Acceptance tests will encompass the following major areas of activity:

a. Subsystems Test

b. Integrated Spacecraft Test and Checkout - ambient conditions

c. Flight Simulation - short duration

d. Dynamics Test

e. Flight Simulation - long duration

f. Final Spacecraft Checkout

31.3.3.2.3.1 Subsystems Test

In order to test each subsystem for operational capability and function, a complete spacecraft subsystems checkout will be performed. This checkout will involve the use of a standardized group of equipment, termed Acceptance Checkout Equipment (ACE). A complete ACE spacecraft (S/C) system includes a ground station, carry-on equipment, and facilities to properly interconnect all components. The ACE is an integrated checkout and display system which provides centralized programmed control of spacecraft checkout operations. It permits manual, semiautomatic, and automatic operational modes for both independent subsystem testing and integrated system testing. The following is a brief description of some, but not necessarily all of the tests that will be performed:

a. Environmental Control Subsystem. ECS power and control circuits are tested prior to energizing other ECS subsystem components. A dry checkout is performed on the water-glycol loop, water management system, the individual sensing devices, and the spacecraft ECS controls and displays. The subsystem is then filled and a similar wet checkout is performed.

b. Reaction Control Subsystem. The RCS propellant gauging is verified by the nucleonic sensors, the computer, and the display panels. All firing circuits and engine inlet valves are verified.

c. Stabilization and Control Subsystem. This subsystem is checked in all control modes at the interface with the RCS. Attitude and rate stabilization and transitional control are checked in response to commands from the control programer. Cross coupling of roll and yaw rate gyros is checked.

d. Communication Subsystem. Communications are checked for proper switching, transmission, and reception. Checks are also made of receiver sensitivity, transmitter power output, and modulation mode compatibility.

e. Power Distribution Test. The dc power distribution system is checked under both ACE and spacecraft internal control, including bus distribution, undervoltage, and external to internal transfer. Similar checks are then performed on the ac system, including checks on the inverter controls.

<u>31.3.3.2.3.2 Integrated Spacecraft Test and Checkout</u>

After the experiments have been integrated with the spacecraft and the experiments have been checked out, an integrated all systems checkout will be accomplished to check the subsystems and experiments for compatibility and function. This checkout will be accomplished using the same checkout equipment as described in the previous paragraph.

<u>31.3.3.2.3.3 Flight Simulation - Short Duration</u>

From the ambient integrated spacecraft test and checkout, the spacecraft will be placed in the thermal vacuum chamber for a short-duration environmental test. This test will determine spacecraft operating characteristics under a simulated free-space environment of temperature and vacuum.

<u>31.3.3.2.3.4 Dynamic Test</u>

The spacecraft is moved to the dynamic test stand where it is subjected to reduced random vibrations. Indications will be monitored on the ACE displays for deviation of test parameters. The dynamic response of the spacecraft at various applied frequencies and at various simulated flight times will be recorded by a network of accelerometers and rate gyros mounted throughout the spacecraft.

<u>31.3.3.2.3.5 Flight Simulation - Long Duration</u>

The spacecraft will again be placed in the thermal vacuum chamber and a long-duration flight simulation test conducted. Throughout the performance of this test the spacecraft is fully operational from both an experiment and subsystem basis. The chamber must be equipped with a source of simulated solar radiation and the walls of the chamber should simulate the infifinite heat sink of space. The test is programmed to evaluate the heat balance and thermal design of the spacecraft throughout the duration of the mission, and demonstrate that all equipment can function as required under the environment of space temperature, hard vacuum, and solar radiation. The spacecraft will be mounted on a rotator-gimbal mount to provide two-axis motion, spin about the centerline of the spacecraft, and inclination relative to the incident simulated solar radiation. The pressure environment will be in the range of 1 X 10^{-9} torr, while the chamber walls will be at approximately liquid nitrogen temperature, -290°C.

31.3.3.2.3.6 Final Spacecraft Checkout

This will be a final acceptance checkout similar to the initial integrated spacecraft checkout. The checkout is required to ensure that the spacecraft is fully operational, has met all of the quality control criteria, and can be formally accepted for shipment to Kennedy Space Center. All test data compiled during In-Process and Flight Acceptance testing provide test results and documentation upon which the final decision for acceptance is based.

31.3.3.3 Experiment Integration

Subcontractor representatives will interface with the Prime Contractor for purposes of experiment/spacecraft integration and planning and preparing tests and test procedures. During test performance they will monitor the experiment equipment to ensure proper operation. They will evaluate data and assist in correcting incompatibilities between the experiment/spacecraft interface. An experiment laboratory concept is to be studied to provide for receipt, storage and test of experiments, and to provide the necessary laboratory and office area for the principle investigators. Laboratory staffing will be studied to provide competent engineering and technical personnel to ensure proper receipt, test, calibration, maintenance, and repair of experiment assemblies and related special test equipment. This same staff will provide the Principle Investigator with required technical assistance and support for those test activities in which it is necessary for the principle investigator to participate. The interfaces of this experiment laboratory will be analyzed to assure that proper support equipment, laboratory data, and necessary procedures are available for experiment installation and integration with the spacecraft. Interfacing of the experiments with the spacecraft will be analyzed for proper installation and testing sequence. Some of the activity that will be required is as follows:

31.3.3.3.1 Laser Experiment Group

31.3.3.3.1.1 Integration, Alignment, and Checkout

The equipment packages for the above experiments consist of the 1-meter and 0.3-meter integral telescopes, the 0.3-meter gimbaled telescope, and the ground receiver telescopic array with its mounting deck. In addition, the spacecraft planet and microwave trackers are included in this discussion because they are required for the acquisition phase. The initial routine activities to be performed (i.e., removing equipment from protective shipping containers, inspection and checkout for shipping and handling damage, system assembly, and normal electrical and mechanical compatibility testing) are the responsibility primarily of Prime Contractor personnel. Subcontractor personnel will support these activities.

After mounting the telescopes, making the required mechanical and electrical connections, and completing the preliminary system compatibility checks, the on-site Subcontractor personnel will align both the 0.3-meter gimbaled telescope axis and the microwave and planet trackers. Because stabilities on the order of 10-15-arc-seconds are sufficient for the planet tracker alignment (and several arc minutes for the microwave tracker), an adequate optical facility of structural steel framework could be constructed at the Prime Contractor Facility. The simulators for the trackers could be on alignment stands: The 1-meter telescope and its integral 0.3-meter telescope would then be boresighted to the 0.3-meter gimbaled telescope axis, using the same facility, and a pair of pyramid prisms. This procedure is identical to that used at the Subcontractor facility for boresighting the 0.3-meter fixed telescope to the 1-meter telescope. The telescopes in the ground station array are boresighted at the Subcontractor facility, upon assembly into the mounting deck. The complete array, therefore, will be aligned as a unit when the mounting deck is assembled.

After alignments are completed, the laser experiments equipment will be tested. All modes of operation will be checked, using electrical power and signals from the spacecraft and simulated inputs from the test consoles. The performance will be monitored by examining electrical output signals only, because no precise optical measurements are possible (or necessary) at this point. The previously completed qualification and acceptance tests, and the special precautions employed in shipping and handling, give assurance that the required optical performance is not degraded in transport. This is comparable to the test philosophy of the OAO program. The Subcontractor engineering representative will assist the Prime Contractor personnel in the performance of this test.

31.3.3.3.2 Large Optics Group

31.3.3.3.2.1 Integration and Checkout

The thin and active primary mirrors and auxiliary equipment for the mirror experiments are contained within the experiment well, except for the interferometer, Foucault tester, and autocollimator (which are stowed when not in use). The routine activities to be performed are similar to those described in paragraph 31.3.3.3.1. The alignment for this experiment is completed at the Subcontractor facility; no additional alignment work is anticipated at the Prime Contractor facility. After completion of the integration of the experiment well, the primary mirror experiment equipment will be tested. Both the interferometer and the Foucault tester will be used, and all modes of operation will be checked. This experiment is complete, containing its own light source and test instrumentation, and requiring no additional simulator, optical bench, or instrumentation. After completion of the testing, the system will be placed in launch configuration. The Subcontractor has prime responsibility for this activity.

31.3.3.3.3 Fine Guidance Experiment No. 12

31.3.3.3.3.1 Integration and Checkout

The equipment for this experiment is mounted within the fine guidance telescope, except for the star trackers, which are mounted directly to the outer surface of the telescope structure. Upon receipt of this package at the Prime Contractor's facility, it will be removed from shipping containers, inspected, and checked out by facility personnel with Subcontractor support. The Prime Contractor personnel will then mount the telescope to the isolation system, and integrate the fine guidance telescope and isolation mounts, mechanically and electrically, with the OTAES vehicle. The optical alignment for this experiment is completed at the Subcontractor facility and no additional effort is required at the Prime Contractor's facility. After integration of the fine guidance telescope and the isolation mounts, and the OTAES vehicle is completed, the system will be tested. The philosophy and limitations to the testing are as discussed previously. The fine guidance telescope contains its own light source built into the cover, to operate the intermediate and fine error sensors. For a check of the star trackers, additional simulators will be required. The performance will be monitored by examining the output error signals from the coarse, intermediate, and fine pointing systems, as each acquires and nulls the image.

31.3.3.4 Prelaunch Activity

When the spacecraft has received final acceptance, it will be shipped to Kennedy Space Center to begin prelaunch checkout. The spacecraft and experiments will receive system verification checks and will be prepared for mating with the launch vehicle. OTAES system design will permit launch pad checkout functions to be preliminary command/discrete functions. This would lend itself to automated checkout with launch control center computer systems. With the total integrated CSM/OTAES/SLA delivery to the launch complex, the on-pad checkout of the OTAES system is considered to be a minimum operational verification. Testing of experiments will be largely limited to visual examination and electrical tests of the go-no-go type. No optical measurements will be attempted on the Laser Group, although simulators will be used where required to perform checkout, for example, of the trackers. For the Large Optics Group, testing will be possible only for a limited portion of the system; for example, the thin mirror will be totally obscured by the bladder. The Fine Guidance telescope may be checked with the built-in light source; simulators will be required for basic checkout of the star trackers. Representatives of Contractor and experiment Subcontractors will be present to conduct these tests and to participate in integration and final checkout activities prior to launch.

31.3.3.5 Costs

These data do not include costs for facilities. The facility costs will be explained specifically in the Preliminary Facility Plan. The schedule (figure 31.3.3.5-1) and costs (table 31.3.3.5-1) are shown below.

Table 31.3.3.5-1 Acceptance Test Costs

Function	Man/Months	Costs
Receiving/Inspection Tests	38	$ 63,000
In-Process Tests	36	60,000
Flight Acceptance Tests	100	170,000
Operation/Maintenance of Space Simulator and Checkout Equipment	-	2,200,000
KSC Test and Checkout	24	42,000
	Total	$2,535,000

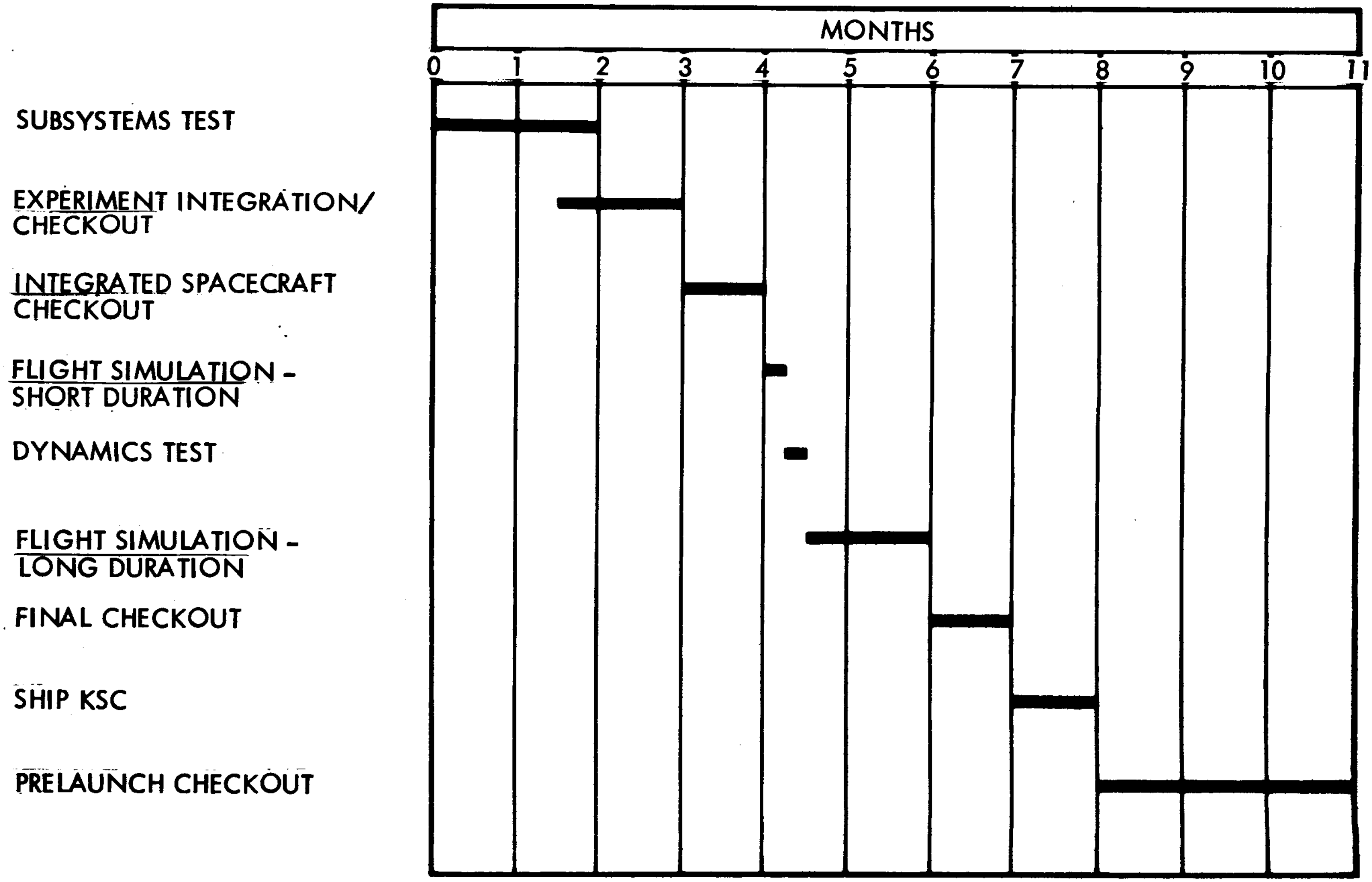

Figure 31.3.3.5-1. Acceptance Test Schedule

31.3.4 Preliminary Facilities Plan

31.3.4.1 Introduction

The preliminary facility requirements which have been identified for the OTAES program are presented in this subsection. The intent of this plan is to identify the requirements for new facilities and modifications to existing facilities necessary to support the development, fabrication, and test of the OTAES spacecraft. There are tradeoffs that must be performed to determine the most feasible approach to new facilities. Alternatives will include either the use of the most proximate NASA test and checkout facility or the building of such a facility at Michoud thereby completing the capability of that facility. The support facilities required are varied and complex; however, utilization of the Michoud Assembly Facility (MAF) will greatly reduce the need for new facility construction.

31.3.4.2 Available Facilities

Michoud Assembly Facility has available, at the present time, several facilities which can be used in the OTAES program with a minimum degree of modification. A brief description of these facilities is listed below:

a. Structures Test Facility. Two load reaction frames are available for structural testing. The larger one is capable of handling specimens up to 25 by 25 by 35 feet, and is designed to have vertical and side load reaction capabilities of 6 million pounds and 1 million pounds respectively. The second reaction frame accommodates specimens up to 14 by 14 by 45 feet, and has vertical and side load reaction capabilities of 1 million pounds and 100,000 pounds, respectively. Increases in loading requirements may be accomplished by adding minor reinforcements. Structural test data acquisition, performed by an analog-to-digital data acquisition system, handles 800 channels of strain gauge information and 150 channels of load, pressure, temperature, and deflection information.

b. Dynamic Testing Facilities. The vibration test system consists of six MB electronics vibration exciters. A description of each of these is listed below:

   (1) C-210 System. A 28,000-force-pound exciter used for general testing, especially in the case of large items requiring high levels.

   (2) C-216 System. A 10,000-force-pound exciter presently used at the remote test facility.

   (3) C-125 System. An exciter that produces 10,000-force-pounds at a 300,000-foot altitude and temperatures ranging from -350 to +500 degrees F.

(4) C-10 System. There are three of these, each rated at 1200-force-pounds. Control consoles for each vibration test system; consists of the standard MB electronics vibration control and associated equipment.

c. Remote Hazards Test Facility. The remote test site, isolated from other operations of MAF, is designed for safe performance of potentially hazardous tests and is currently being used for cryogenic tests. With a small amount of modification, this facility would be used for testing of the reaction control system thrusters.

d. Clean Room. The present clean room at MAF could be used for OTAES spacecraft assembly to ensure the absence of contaminents in vital parts of the craft.

e. High Pressure Test Facility. Three pneumatic testing systems are available at MAF which can be operated with either helium or nitrogen. There are four test cells completely equipped to handle flow rates below 1000 SCFM with nitrogen or compressed air at 3500 psig and helium up to 6000 psig. One of the systems can deliver programmed flow and pressure so that operation simulations can be obtained within the full range of the equipment. A facility which allows temperature control of gasses from -300 to +500 degrees F at flow rates exceeding 20,000 SCFM for 3 minutes is also available. A central distribution system services the entire laboratory with high pressure air at 3500 psig. Potentially dangerous high flow pneumatic testing is performed at the Remote Test Site. The higher pressure test facilities at MAF are capable of meeting any requirements of the OTAES program.

f. Electrical Facility. For test and acceptance of OTAES electrical equipment, an electrical facility with MB vibrator's, temperature chambers, a screen room, and other related equipment are required. These facilities are presently available and will not require modification.

g. Electrical Cabling Facility. Electrical cabling will be fabricated and tested at the assembly plant for the OTAES spacecraft. The Prime Contractor has the necessary facilities available and they will not require modification.

31.3.4.3 New Facilities

Several new facilities will be required to support the OTAES spacecraft effort. These facilities and a brief description of them are as follows:

a. Acceptance Checkout Equipment (ACE). The acceptance checkout equipment is a standardized group of equipment which has been developed to conduct a complete spacecraft checkout. It is an integrated checkout and display system which provides centralized, programed control of spacecraft checkout operations. Both independent subsystem testing and integrated system testing are accommodated. There are presently four of these facilities in the country, built for use by NASA for the Apollo program. It may be possible during the OTAES program time frame that one of these facilities will be available for installation at MAF.

b. Space Simulator. The OTAES spacecraft will require checkout in a thermal vacuum chamber. The chamber must be large enough to accommodate the entire spacecraft in an environment that is similar to that of outer space. The vacuum chamber will be required to produce a pressure of 10^{-9} mm Hg at approximately -300 degrees F. A solar simulator will also be required to simulate solar radiation.

c. Small Thermal Vacuum Chamber. A small chamber, approximately 3 feet by 5 feet, with cold wall and accurate solar simulation is required for OTAES spacecraft fabrication support. This facility will be necessary for component qualification and also for use as a solar cell test facility. With respect to solar cells, it will be used to select cells and module interconnection so that specifications can be prepared. The chamber will be used to batch test solar cells and modules in parallel with the solar power system subcontractor. Vacuum requirements are 10^{-9} mm Hg.

d. Solar Panel Deployment Facility. A large area with a structure capable of supporting solar panel arrays is required. This facility will be used to perform deployment tests and checkout on the panel deployment mechanism.

e. Electrochemical Test Facility. This is a test cell with consoles, bell jars, and a small vacuum chamber with a thermal wall. This is required for evaluating fuel cell and battery concepts and for performing acceptance tests.

f. Air-Bearing Table. An air-bearing table is required to isolate the OTAES spacecraft from unwanted vibrations during stabilization, control subsystem alignment, and experiment alignment.

g. Assembly Area. The construction of a manufacturing assembly room of approximately 4500 square feet will be required to assemble the spacecraft and install the subsystem and experiments. This room will require a clean atmosphere and can be readily constructed in the present manufacturing area available at Michoud.

31.3.4.4 Development Times

Modification and construction of support facilities for OTAES Spacecraft fabrication have been divided into several phases. The first phase is the definition phase and encompasses identification and writing of specifications for all areas that are to be impacted by modification or construction. The second phase is the procurement phase which is the time period necessary for obtaining the required materials for the modification or construction. The third phase is the installation phase which allows time for the actual construction or modification to be completed. The last phase is the checkout period in which the modifications and constructions of the OTAES spacecraft facilities are tested and checked for reliability.

Figure 31.3.4.4-1 shows the required times assigned to each of the four phases for the acceptance checkout equipment, the assembly area, the structure and dynamic facility modifications, the space simulator, and all other facilities combined.

31.3.4.5 Costs

The estimated costs for the above modification and construction are listed below:

Acceptance checkout equipment	$5,000,000
Assembly area and clean room	1,500,000
Structure and dynamic facility modification	1,000,000
Space simulator	2,500,000
Plant modifications	600,000
Small thermal vacuum facility	35,000
Solar panel deployment facility	250,000
Electromechanical test facility	65,000
Air bearing table	150,000
KSC checkout equipment	1,000,000
Total	$12,110,000

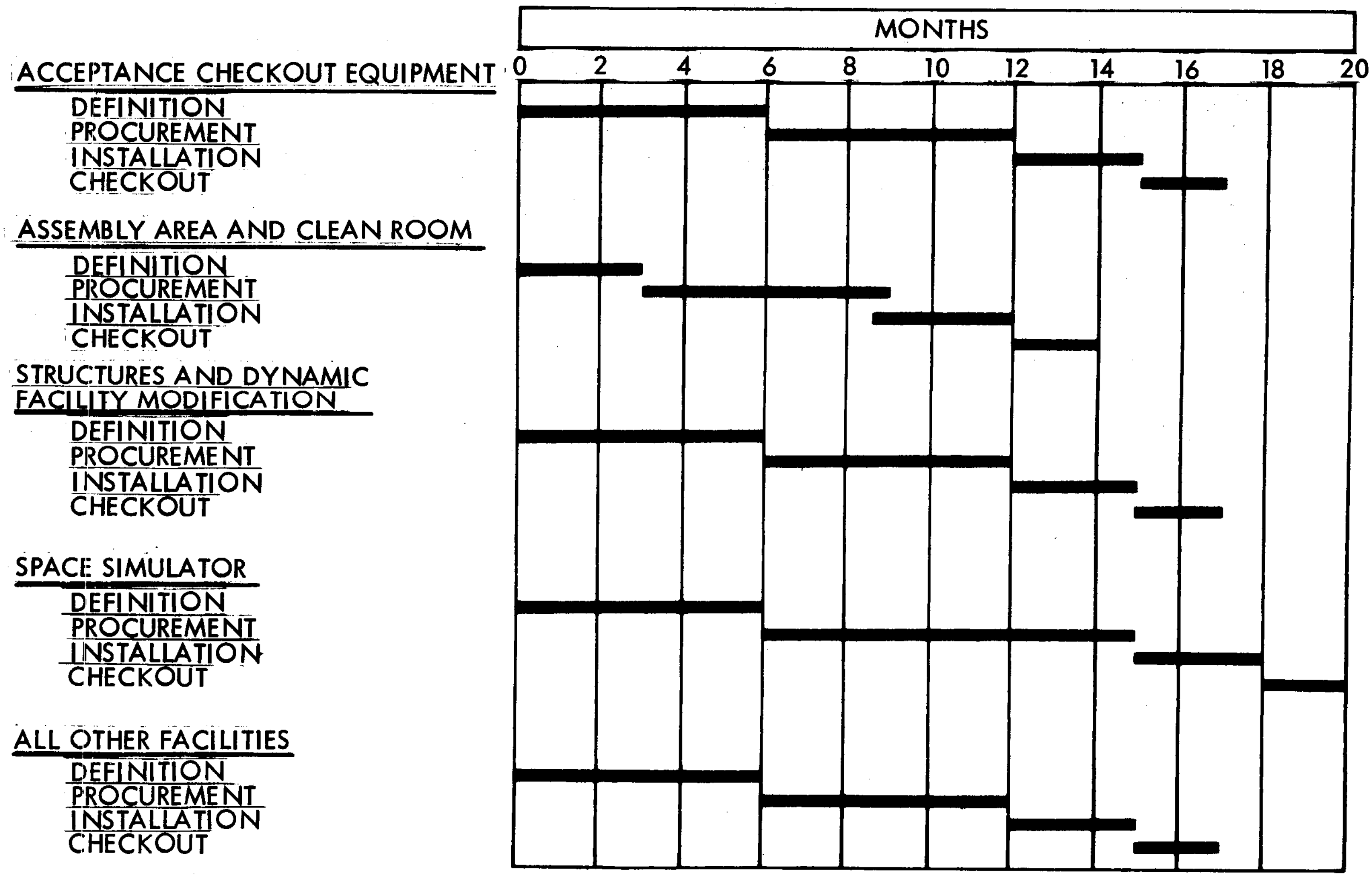

Figure 31.3.4.4-1. Facilities Construction and Modification Schedule

31.4 SCHEDULE PLAN

31.4.1 Present Program Schedule

The assumed schedule for the OTAES program is 54 months from the authority to proceed for Phase B until the launch of the optical technology experiment spacecraft (OTES). The program plan is graphically displayed in the time-oriented master schedule, figure 31.4.1-1. This schedule depicts the major activities and events occuring in the program and the approach selected for the attainment of program objectives. Figures 31.4.1-2 through 31.4.1-6 are summary schedules for the major program activities. Detailed schedules and cost estimates are provided in the sections listed below:

Prerequisite Technology Development (PRT)	31.1
Experiment Related Plans	31.2
Spacecraft Related Plans	31.3

31.4.2 Schedule Compression

One of the many areas which has received major emphasis is compression of the OTAES program schedule to meet the earliest launch date which is both technically and economically feasible. A review of all facets of the program indicates that a 50-month schedule is technically feasible using the baseline configuration in this report.

To meet a 50-month schedule, adequate OTAES-related mission-related technology funding must be provided promptly to ensure that all PRT development activities are performed at an accelerated rate. The OTAES spacecraft preliminary design, overall configuration, and systems specifications can be prepared concurrently with the PRT development. However, because the purpose of the spacecraft is to provide a vehicle to support the experiments, much of the detailed design cannot be accomplished until the technology advances have been achieved and the proposed methods and techniques demonstrated. The minimum time to accomplish the PRT activities is estimated to be 19 months.

Because the PRT activities have been compressed to 19 months, detailed design of the experiments and spacecraft can also be accomplished earlier, which will allow a compression of the Phase D schedule. From a comparison of comparable spacecraft programs, it is estimated that 29 months would be the minimum time required for Phase D.

Figure 31.4.2-1 portrays a 50-month schedule plan which is technically feasible. It must be emphasized that the overall program cost will be increased because additional manloading will be required, and no time has been allowed for unforeseen problems. The overall cost increase is estimated to range from 15 to 33 per cent (see figure 31.4.2-2).

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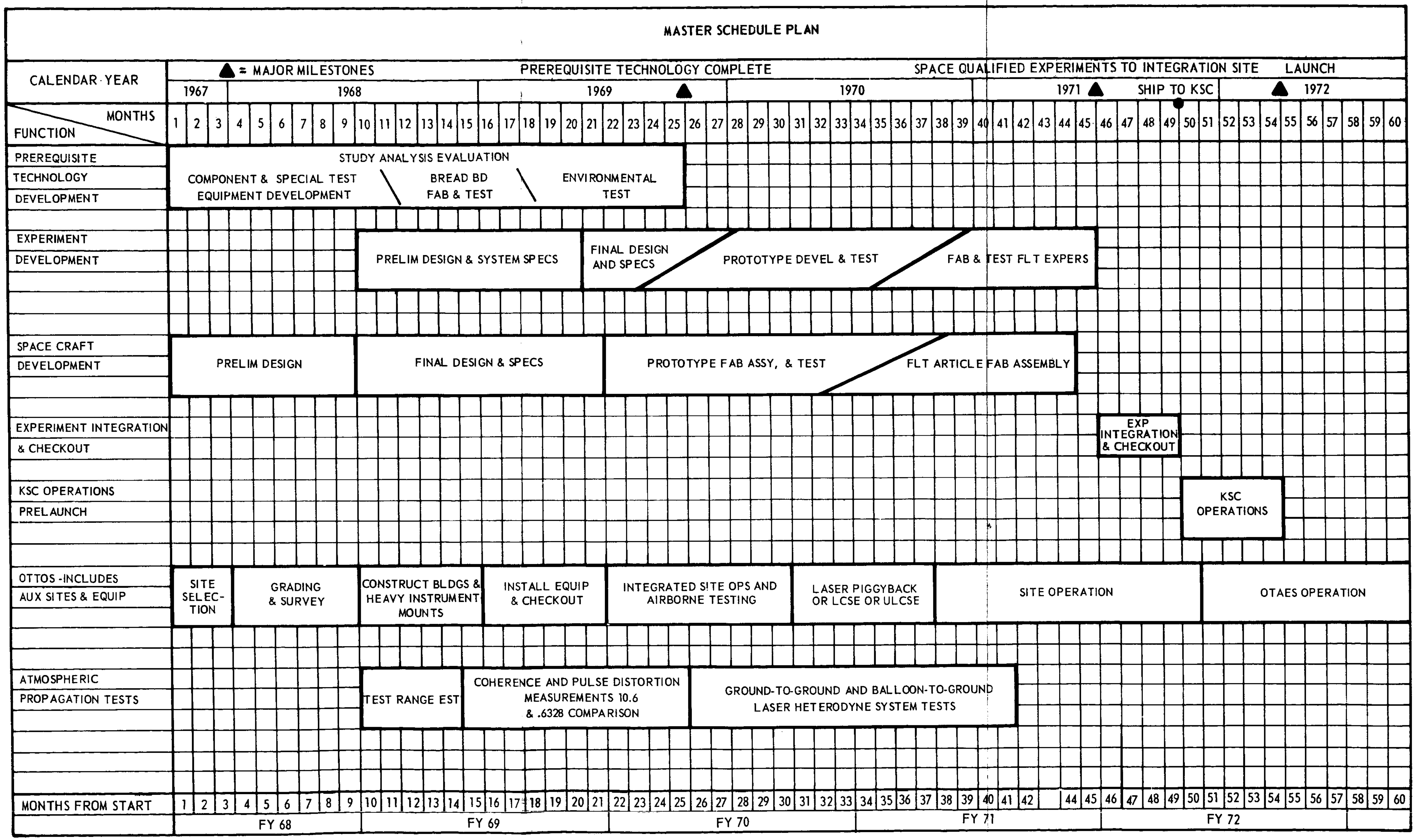

Figure 31.4.1-1. Master Schedule Plan

LASER GROUP SCHEDULE PLAN

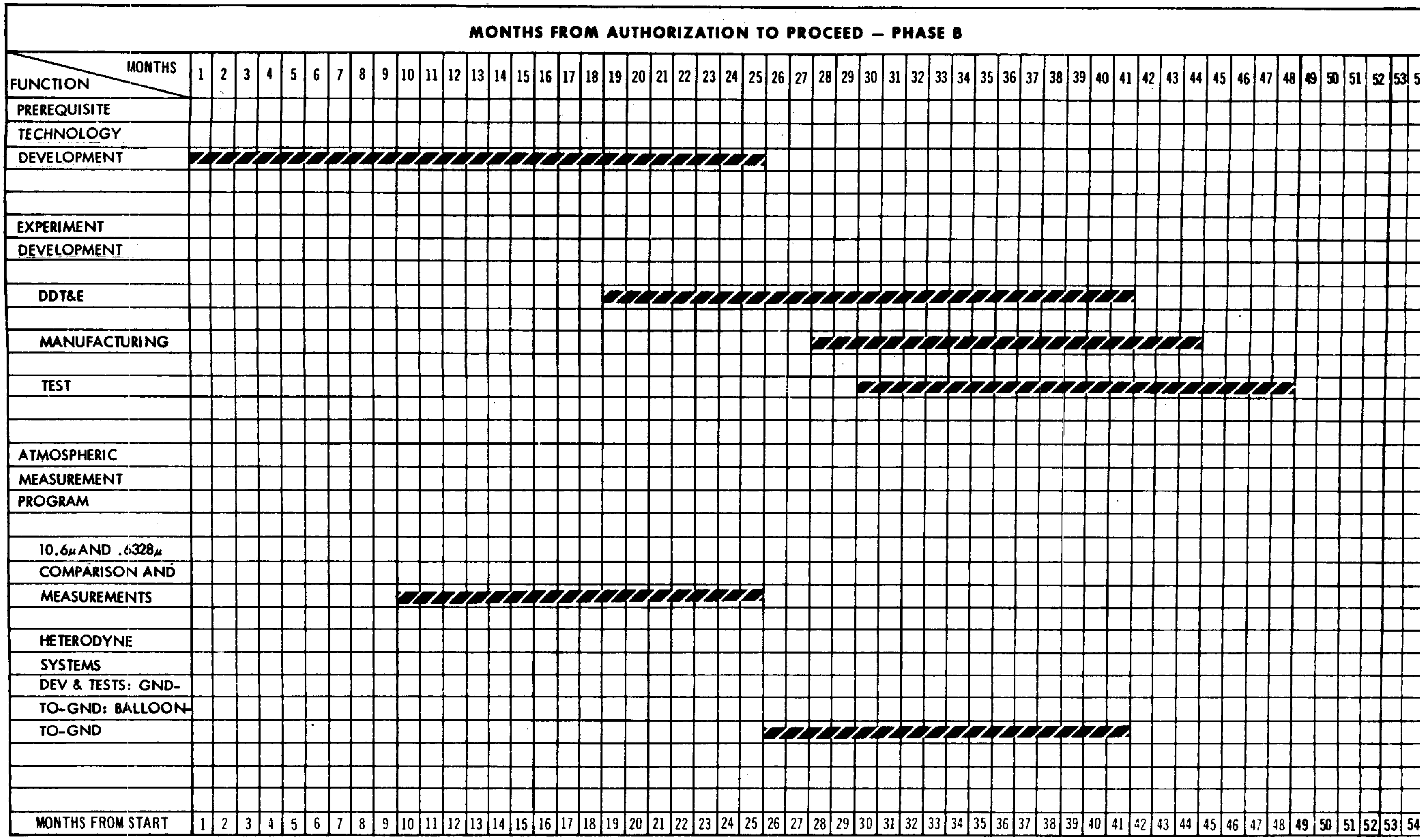

Figure 31.4.1-2. Laser Group Schedule Plan

LARGE OPTICS GROUP SCHEDULE PLAN

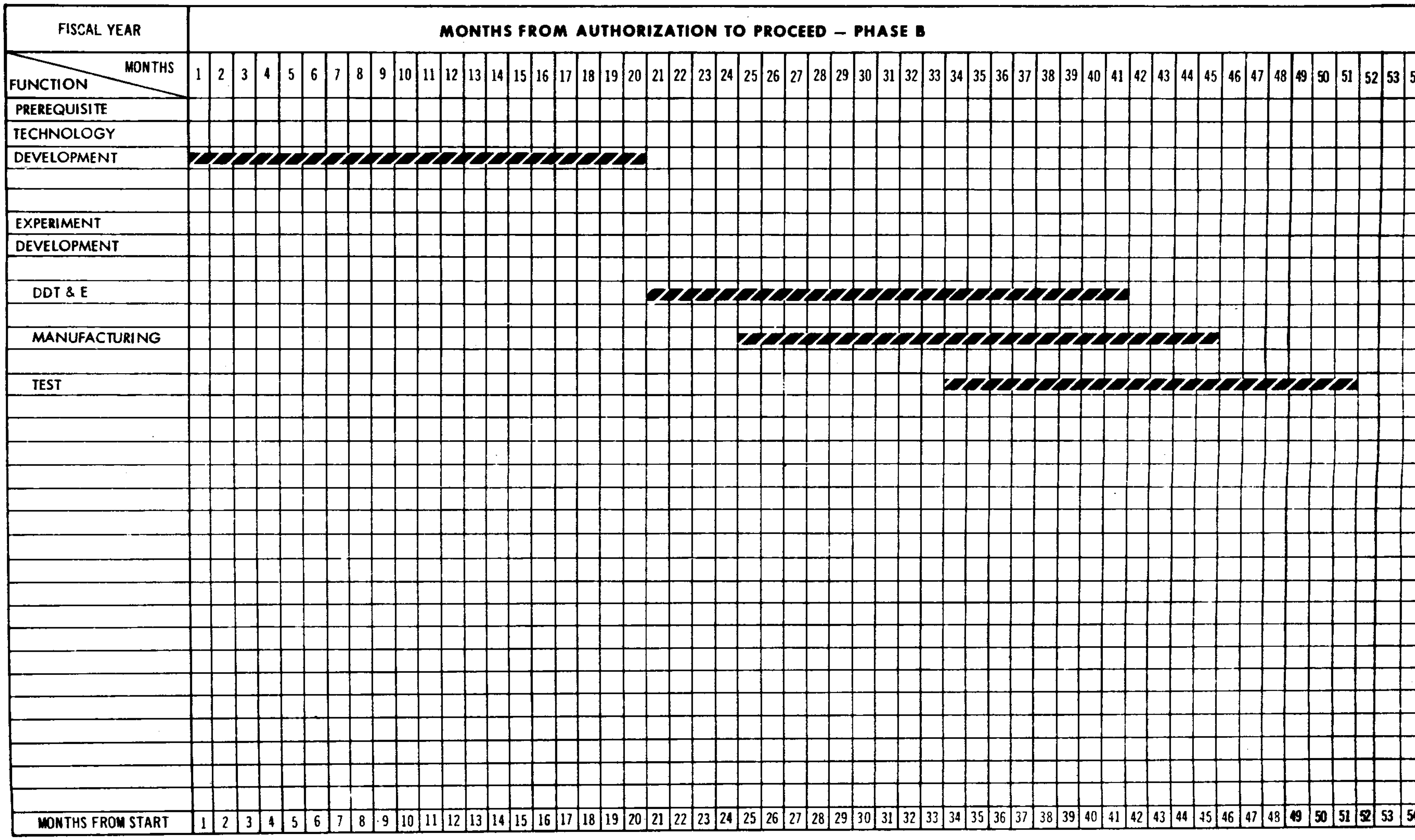

Figure 31.4.1-3. Large Optics Group Schedule Plan

FINE GUIDANCE AND ISOLATION COMPARISON GROUP SCHEDULE PLAN

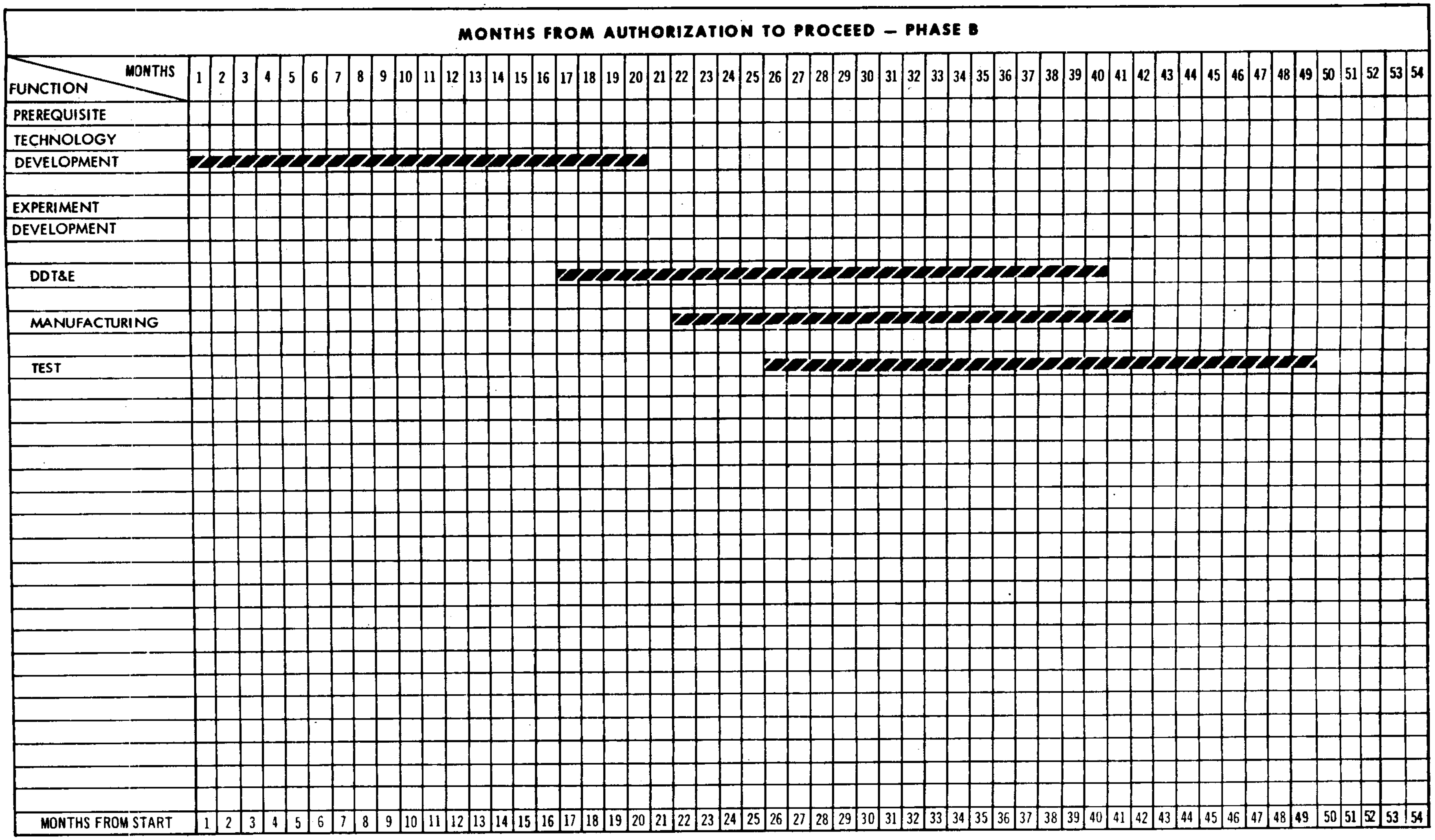

Figure 31.4.1-4. Fine Guidance and Isolation Comparison Group Schedule Plan

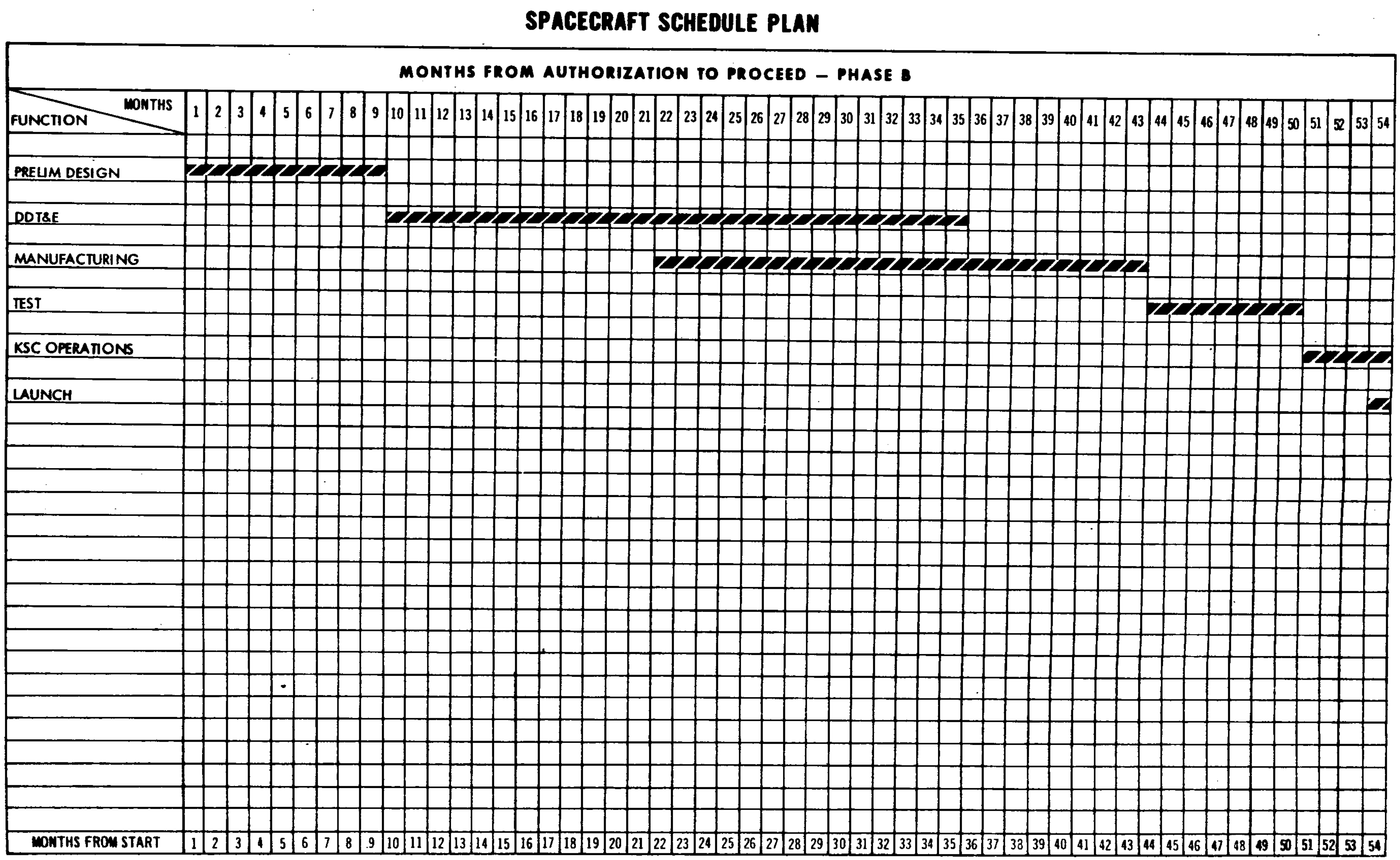

Figure 31.4.1-5. Spacecraft Schedule Plan

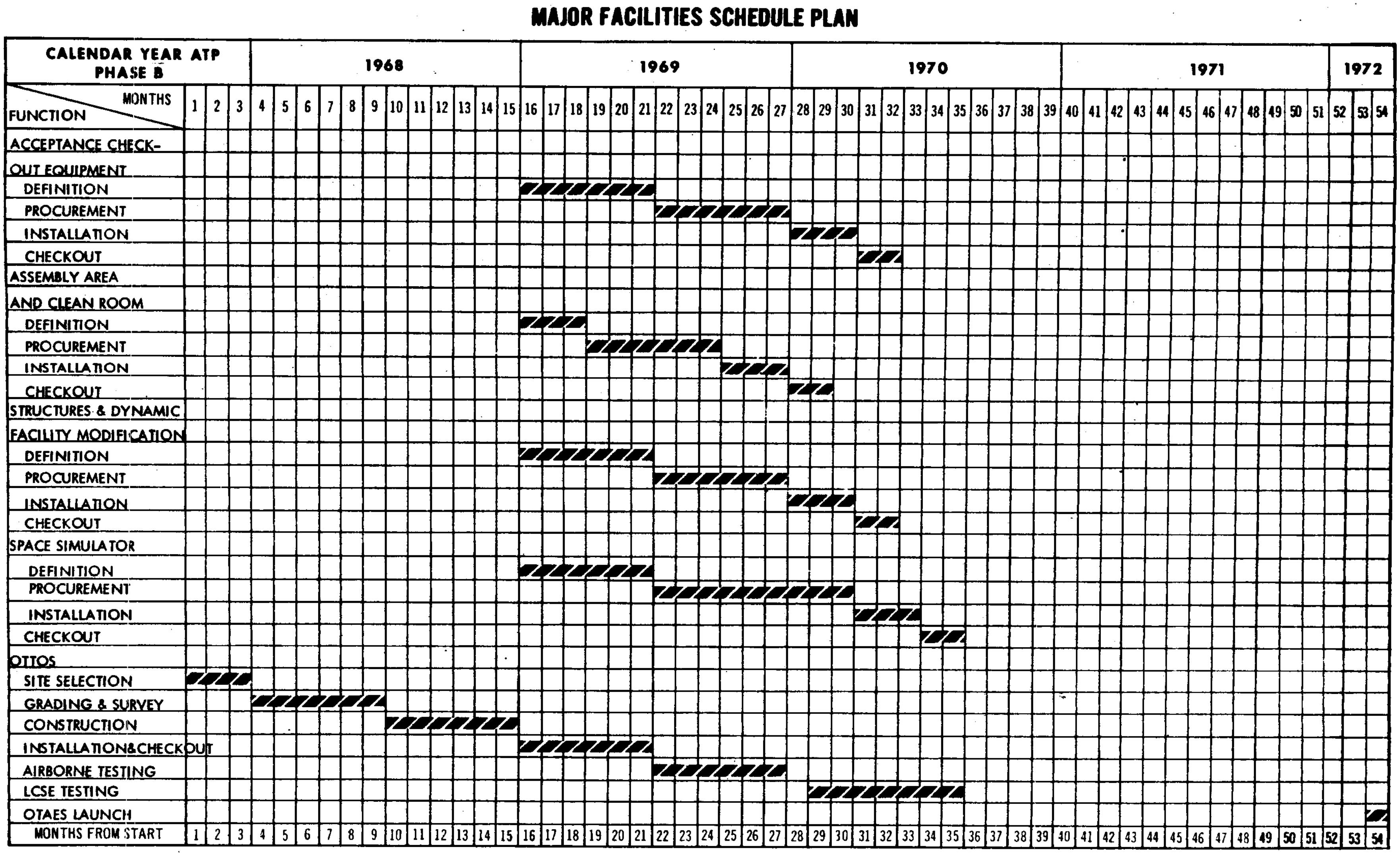

Figure 31.4.1-6. Major Facilities Schedule Plan

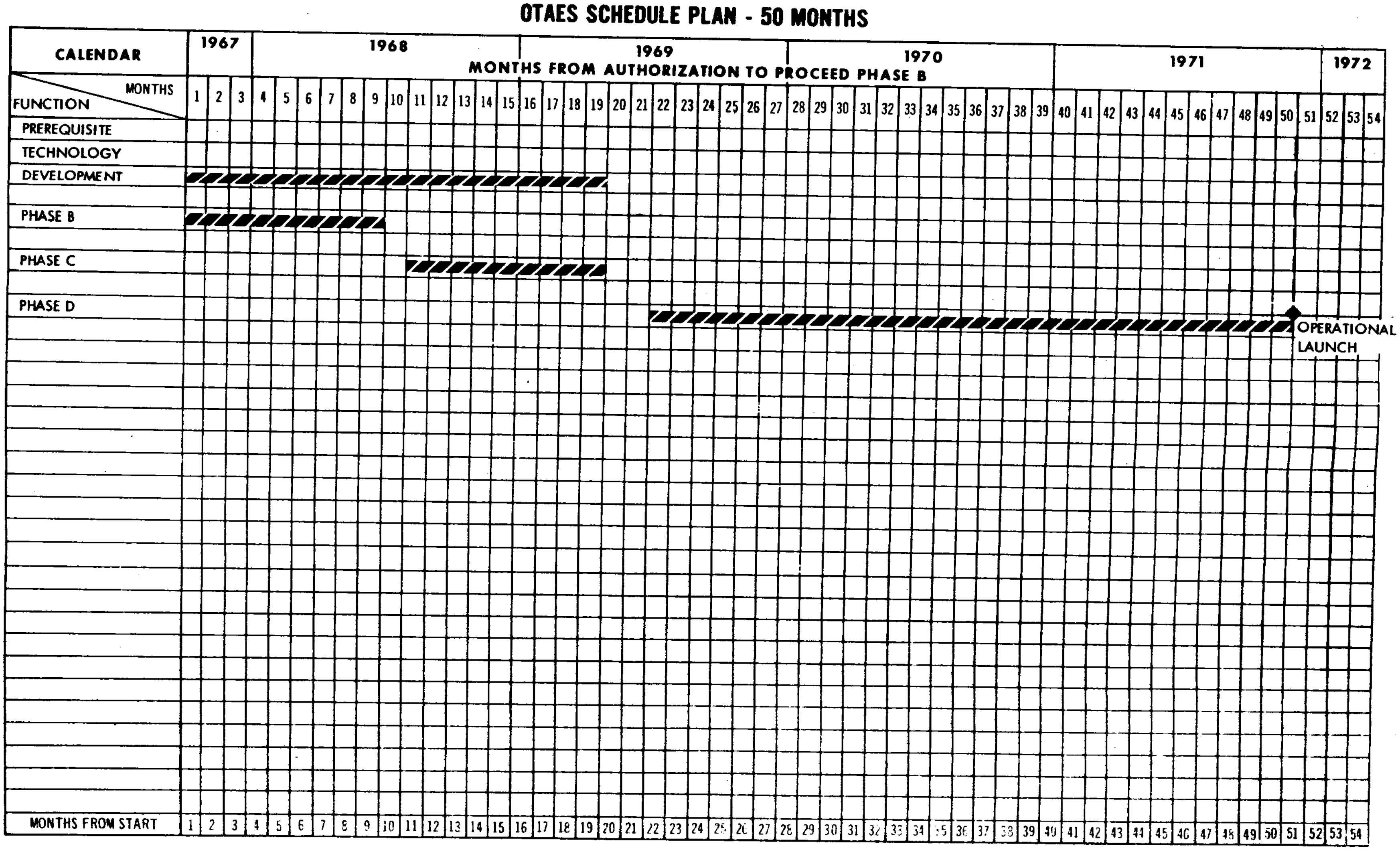

Figure 31.4.2-1. OTAES Schedule Plan--50 Months

In Phase B the entire schedule will be continuously reviewed and refined, placing appropriate emphasis on the technology advances achieved, research and development pending, and the recommended spacecraft and experiment configurations.

The optimum overall OTAES program schedule at the present time is 54 months from ATP-Phase B until launch. The minimum feasible schedule is 50 months. Further compression is not feasible because:

a. The increased costs involved are disproportionate to the time saved (figure 31.4.2-2).

b. The extensive testing required at the subsystem, system, and spacecraft levels to provide a man-rated spacecraft cannot be accomplished in a shorter period without both a marked increase in cost, and the unsupportable assumption that all testing will be accomplished satisfactorily the first time and on schedule.

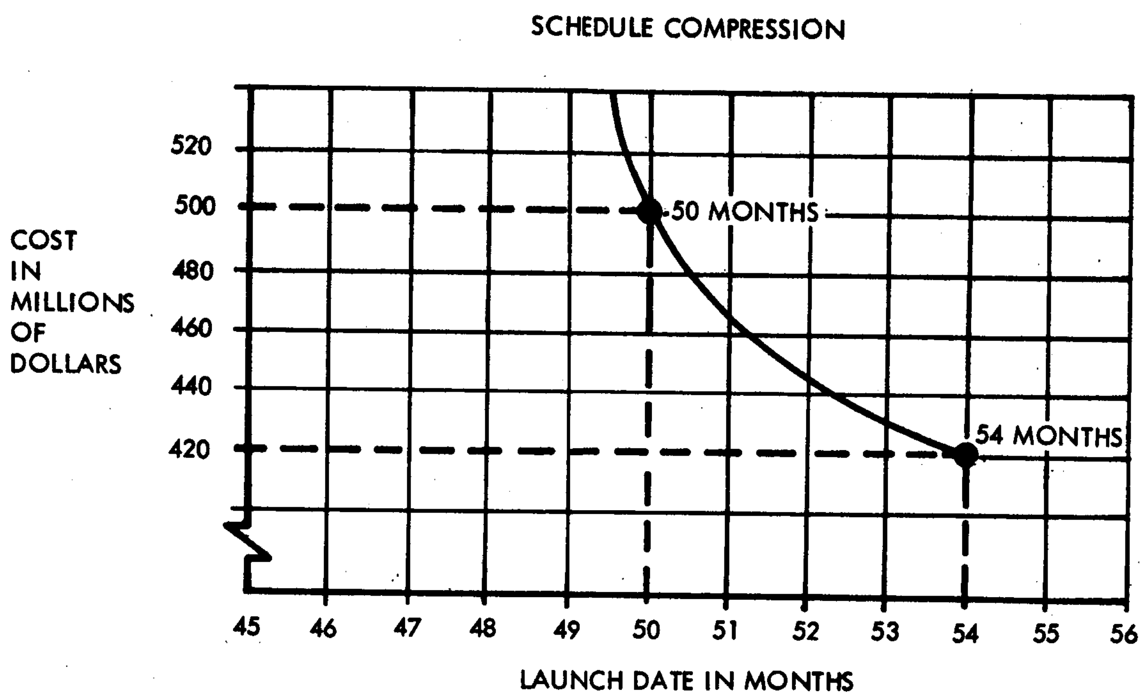

Figure 31.4.2-2. Schedule Compression—50 Month Schedule

31.5 COST PLAN

Cost data are required early in proposed NASA space programs for:

1) The assessment of the fiscal practicability and time phasing of the program, considering other demands on the limited resources available; and

2) inclusion in the long-range plans that ultimately will define the course of the national space program.

The OTAES approach presented in this study was selected to demonstrate feasibility and provide preliminary gross program cost estimates.

In Phase B an evaluation of the alternate conceptual approaches will be made and a single approach recommended. Refined cost data will be provided in detail at the subsystem level.

31.5.1 Summary

The estimated total program cost for OTAES is $423.3 million (table 31.5.1-1). This includes Research and Advanced Technology Development, design and development of the 13 hardcore experiments, modified LM spacecraft, launch vehicle (Saturn V), supporting spacecraft (CSM, SLA, LES), and ground systems.

TABLE 31.5.1-1

TOTAL PROGRAM COST

Activity	Cost (Millions of Dollars)
Prerequisite Technology Development	6.4
Experiments	14.3
Spacecraft	136.6
Facilities	24.4
Launch Vehicle and Support Spacecraft	229.2
Program Management	12.4
TOTAL	423.3

Percentage distribution of the total program cost, by major program element, is shown in figure 31.5.1-1.

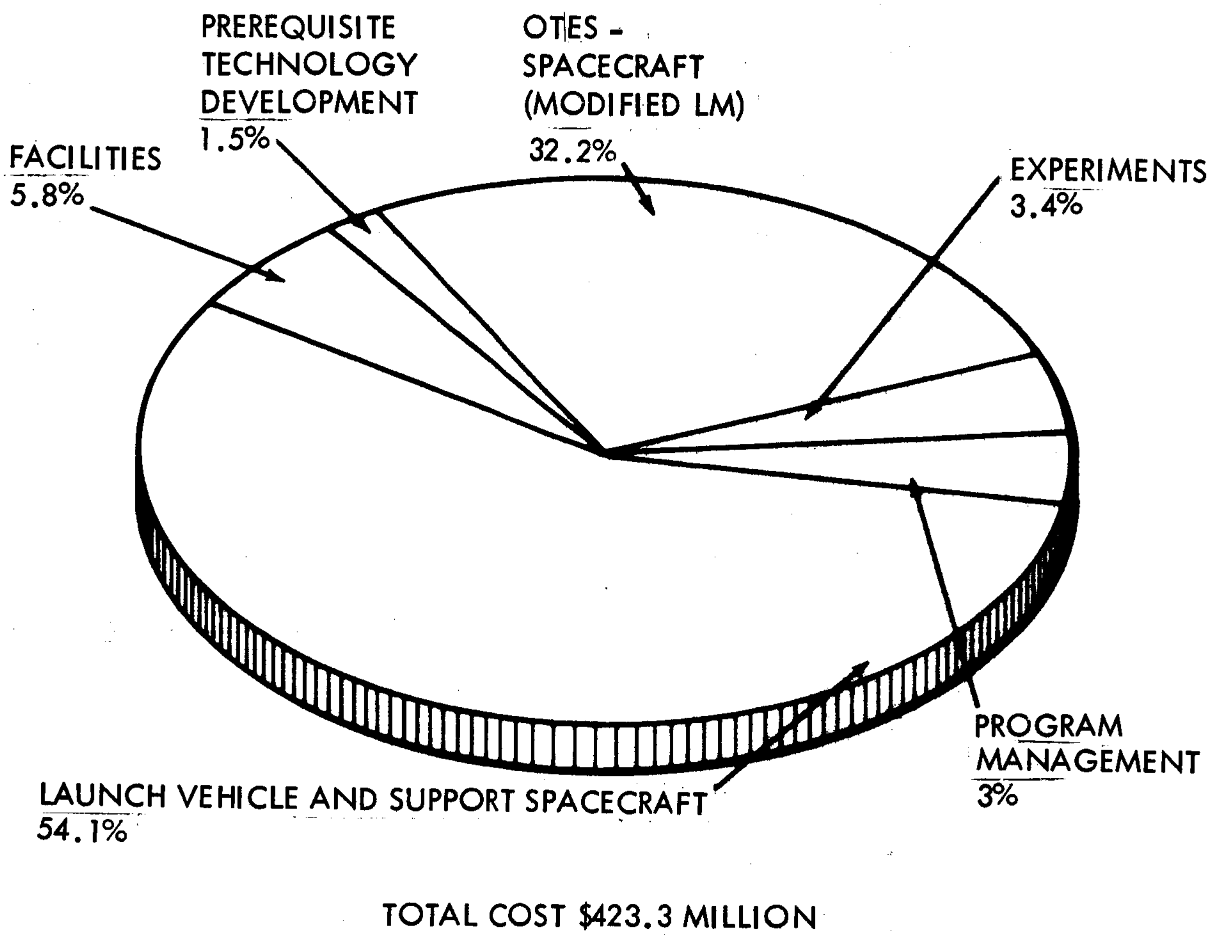

Figure 31.5.1-1. OTAES Program Cost Distribution

31.5.2 Prerequisite Technology Development Costs

Preparation of the cost estimates for prerequisite technology development (research and advanced technology) has received major emphasis, because supporting research and technology funds will be required to conduct the research and develop the advanced techniques and methods which must be demonstrated before flight experiment hardware can be designed. The estimated total cost for prerequisite technology development is $6.4 million.

Cost estimates for this development were made by normal contractor estimating. Detailed task breakdowns and development plans were used in estimating man-hours and material costs.

The principal prerequisite technology activities are studies, analyses, breadboard and model development, and testing. Cost estimates for the three experiment groups (Laser, Large Optics, and Fine Guidance and Isolation Comparison) and the Laser Heterodyne System tests are presented in table 31.5.2-1. These estimates include facilities and special test equipment required for prerequisite technology development. Detailed cost breakdowns and schedules are provided in section 31.1.

TABLE 31.5.2-1

PREREQUISITE TECHNOLOGY DEVELOPMENT COST SUMMARY

Activity		Cost (Millions of Dollars)
Laser Group		3.68
Laser Heterodyne System Tests (Ground-to-Ground and Balloon-to-Ground)		0.83
Large Optics Group		0.88
Fine Guidance and Isolation Comparison Group		0.98
	TOTAL	6.37

31.5.3 Experiment Development Costs

Cost estimates for experiment development are based on the conceptual designs presented in this report and, depending upon the results of the prerequisite technology development program, are subject to revision. Refined estimates reflecting technological advances made and the recommended optimum configuration of spacecraft and experiments will be submitted in the Phase B report.

The estimated total cost for experiment development is $14.3 million.

The principal activities in experiment development include DDT&E, manufacturing, and testing. Cost estimates for the three experiment groups are presented in table 31.5.3-1.

TABLE 31.5.3-1

EXPERIMENT DEVELOPMENT COST SUMMARY

Activity		Cost (Millions of Dollars)
Laser Group		7.7
Large Optics Group		2.2
Fine Guidance and Isolation Comparison Group		4.4
	TOTAL	14.3

Detailed cost breakdowns and schedules are provided in section 31.2.

31.5.4 Spacecraft Development

Cost estimates for spacecraft development are based on a modified Lunar Module, a configuration selected to demonstrate feasibility. In Phase B the preliminary design of the selected configuration will be prepared and detailed costs will be developed at the subsystem level.

The estimated total cost for spacecraft development is $136.6 million.

The principal activities in spacecraft development include DDT&E, manufacturing, and testing at the subsystem and assembled spacecraft level. Experiment integration and final checkout costs are also included. Cost estimates for the major activities are presented in table 31.5.4-1.

TABLE 31.5.4-1

SPACECRAFT DEVELOPMENT COST SUMMARY

Activity		Cost (Millions of Dollars)
DDT&E (prototype and structural unit design, fabrication, and test)		54.2
Flight Article (manufacture and test)		41.9
Backup		40.5
	TOTAL	136.6

Detailed schedules and costs are provided in section 31.3.

31.5.5 Facilities Cost

The costs of facilities required for implementation of the developmental and operational phases of the OTAES program are summarized in this paragraph. The costs for modification of existing facilities and for construction of new facilities are presented in table 31.5.5-1.

TABLE 31.5.5-1

FACILITIES COST SUMMARY

Activity		Cost (Millions of Dollars)
Contractor/Subcontractor		12.8
Cape Kennedy		1.0
Operational Support		10.6
	TOTAL	24.4

31.5.5.1 Subcontractor Facility Requirements

Subcontractor facility requirements include a 1,600-square-foot addition to the optical systems laboratory, temperature chamber, environmental chamber, two special consoles, two optical benches, two special shock tables, and 400 square feet of test and storage area for laser and telescope integration and test. Detailed descriptions and costs are provided in section 31.2.

31.5.5.2 Contractor Facility Requirements

Contractor requirements include laboratory facilities to support the development and test of the experiment No. 13 telescope suspension systems, and those facilities required for manufacture, modification, and testing of the spacecraft.

Experiment support facilities are made up of five subsystems: the suspension test fixture, disturbance environment simulator, telescope dynamic simulator, instrumentation system, and environmental control system. A detailed description is provided in subsection 31.2.4.

New facilities required to support the OTAES spacecraft are: acceptance checkout equipment, a space simulator large enough to accommodate the entire spacecraft, a small thermal vacuum chamber, a solar panel deployment facility, electrochemical test facility, air-bearing table, and a new 4,500-square-foot assembly area. Subsection 31.3.4 contains descriptions and estimated costs of each of these requirements.

31.5.5.3 Special OTAES Testing

It is estimated that $1 million will be required for special testing and checkout of the OTAES at KSC.

31.5.5.4 Operational Support Facilities

Operational support facilities costs include the site selection, construction, fitting out and operational testing of the OTTOS, auxiliary site, and a supporting troposcatter and radio theodolite station complex required to support the OTAES mission. A description of the proposed OTTOS, equipment requirements, estimated cost breakdown, and implementation schedule are provided in subsection 31.2.4.

31.5.6 Launch Vehicle and Supporting Spacecraft Costs

Cost estimates for the launch vehicle, supporting spacecraft, and launch operations are based on information obtained from NASA-MSFC. A summary of the launch vehicle and supporting spacecraft costs for the baseline OTAES mission are presented in table 31.5.6-1.

TABLE 31.5.6-1

LAUNCH VEHICLE COST SUMMARY

Component/Activity		Cost (Millions of Dollars)
Saturn V		121.9
Command Module		40.0
Service Module		20.0
Launch Escape System		1.7
Spacecraft Launch Adapter		0.6
Launch Operations		45.0
	TOTAL	229.2

31.5.7 Program Management Costs

Program management costs include estimated costs for a management information system and overall management effort. It is assumed that these costs will approach 3 per cent of the total program costs, or approximately $12.4 million.

NASA program management costs have not been included in the OTAES program costs.

31.5.8 Astronaut Training Costs

Astronaut training programs, facilities, and training equipment have not been included in this study. A preliminary training plan including schedules, costs, and facilities will be provided in the Phase B study.

32.0 OTAES MISSION ECONOMIC ALTERNATIVES

The OTAES mission economic alternatives that are currently being considered are presented in this section. Informal estimates were obtained from NASA-MSFC for the Apollo spacecraft, Saturn V launch vehicle, the Atlas/Centaur, and launch operations. Costs for the Uprated Saturn I, the Improved Saturn I, the Uprated Saturn I/Minuteman, and the attendant launch operations were taken from the reports of the Saturn Improvement Studies (NAS 8-11369 and NAS 8-20260) performed by Chrysler for NASA-MSFC. These estimates are based on the ground rules and guidelines determined by NASA for use in those specific studies, and do not include a 3 per cent charge for program management. Subsequent ground rule changes for the use of these vehicles in other programs would reduce the cost. All other costs were derived from the studies conducted by the team of Chrysler Corporation Space Division, Kollsman Instrument Corporation, and Sylvania Electronic Products, Inc. These alternatives are typical, and serve as basic building blocks from which the total program alternatives can be optimized in the Phase B Study.

Eight typical mission alternatives are summarized in table 32.0-1. Table 32.0-2 illustrates a typical breakdown of an OTAES spacecraft cost using OTAES spacecraft No. 1 as an example. Table 32.0-3 is a summary of the costs of the 13 flight alternatives using total flight alternative costs (Column a), and total cost less launch vehicle and operations (Column b). The type of spacecraft, mission, launch vehicle, and number of experiments is presented in figures 32.0-1 through 32.0-8. Detailed cost sheets, included with each of these figures, contain two useful cost figures for each alternative. The first cost figure (Column a), derived for use in the total mission alternative costing, combines the cost of the experiments, experiment spacecraft (flight, backup, and qualification units), support spacecraft launch vehicle, and launch operations. The second cost figure (Column b), used to develop OTAES mission funding information, combines the cost of the experiments, experiment spacecraft (flight, backup and qualification units), and support spacecraft. This total figure does not include the cost of the launch vehicle(s) nor launch operations.

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MISSION ALTERNATIVE LISTING

				MISSION ALTERNATIVES	1			2		3			4	5	6	7	8
				FLIGHT ALTERNATIVE COST (MILLION $)	410.9	562.3	587.3	217.6	326.6	574.8	503.6	413.6	339.7	607.6	514.7	515.2	422.3
				FLIGHT ALTERNATIVES →	A SATURN V	B SATURN V	C SATURN V	D IMPROVED SATURN IB/ CENTAUR	E SATURN V	F SATURN V	G SATURN IB/MINUTEMAN + IMPROVED SATURN IB/CENTAUR	H	I IMPROVED SATURN IB/ CENTAUR, SATURN IB	J IMPROVED SATURN IB/ CENTAUR, SATURN IB, SATURN IB	K IMPROVED SATURN IB/ CENTAUR, SATURN IB/ MINUTEMAN, ATLAS/CENTAUR	L IMPROVED SATURN IB/ CENTAUR, SATURN IB/ MINUTEMAN, ATLAS/CENTAUR	M IMPROVED SATURN IB/ CENTAUR, ATLAS/CENTAUR, ATLAS/CENTAUR
SPACECRAFT	ORBIT	EXPERIMENTS	MANNED	UNMANNED													
OTAES #1 (LM)	SYNCHRONOUS	1-13	X		●												
OTAES #2 (NEW)	SYNCHRONOUS	1-13	X			●											
OTAES #3 (MOTEM)	SYNCHRONOUS	1-13	X				●										
OTAES #4 (NEW)	SYNCHRONOUS	1-13		X				●	●								
OTAES #5 (NEW)	SYNCHRONOUS	1-9		X						●	●	●	●	●	●	●	●
OTAES #6 (NEW)	LOW EARTH	10-13	X							●	●						
OTAES #7 (LM)	LOW EARTH	10-13	X									●					
OTAES #8 (NEW)	LOW EARTH	10-13		X									●				
OTAES #9 (LM/ATM)	LOW EARTH	10-11	X											●	●		
OTAES #10 (NEW)	LOW EARTH	10-11		X												●	●
OTAES #11 (LM/ATM)	LOW EARTH	12-13	X											●		●	
OTAES #12 (NEW)	LOW EARTH	12-13		X											●		●

TABLE 32.0-1 MISSION ALTERNATIVE LISTING

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The following table shows a breakdown of spacecraft costs for the OTAES spacecraft No. 1. DDT&E costs include testing and fabrication of the qualification unit and the structural test unit. The costs in this table are preliminary gross estimates only, but may be considered as representative of the cost breakdown for the other alternative spacecraft shown in this section.

TABLE TABLE 32.0-2

OTAES SPACECRAFT NO. 1 COSTS

DDT&E	$54,300,000
Subsystems (New or Modified)	32,000,000
Installation and Integration	6,000,000
Facilities	12,000,000
Testing	2,500,000
Tooling	1,250,000
Backup Unit	40,550,000
Total	$148,600,000

TABLE TABLE 32.0-3

FLIGHT ALTERNATIVE COST COMPARISON
(Thousands of Dollars)

FLIGHT ALTERNATIVE	COLUMN a TOTAL COST	COLUMN b TOTAL COST LESS LAUNCH VEHICLE AND OPERATIONS
A	410,900	243,900
B	562,300	395,300
C	587,300	420,300
D	217,600	159,600
E	326,600	159,600
F	574,800	407,800
G	503,600	409,400
H	413,600	319,400
I	339,700	248,700
J	607,600	477,200
K	514,700	408,500
L	515,200	409,000
M	422,300	340,300

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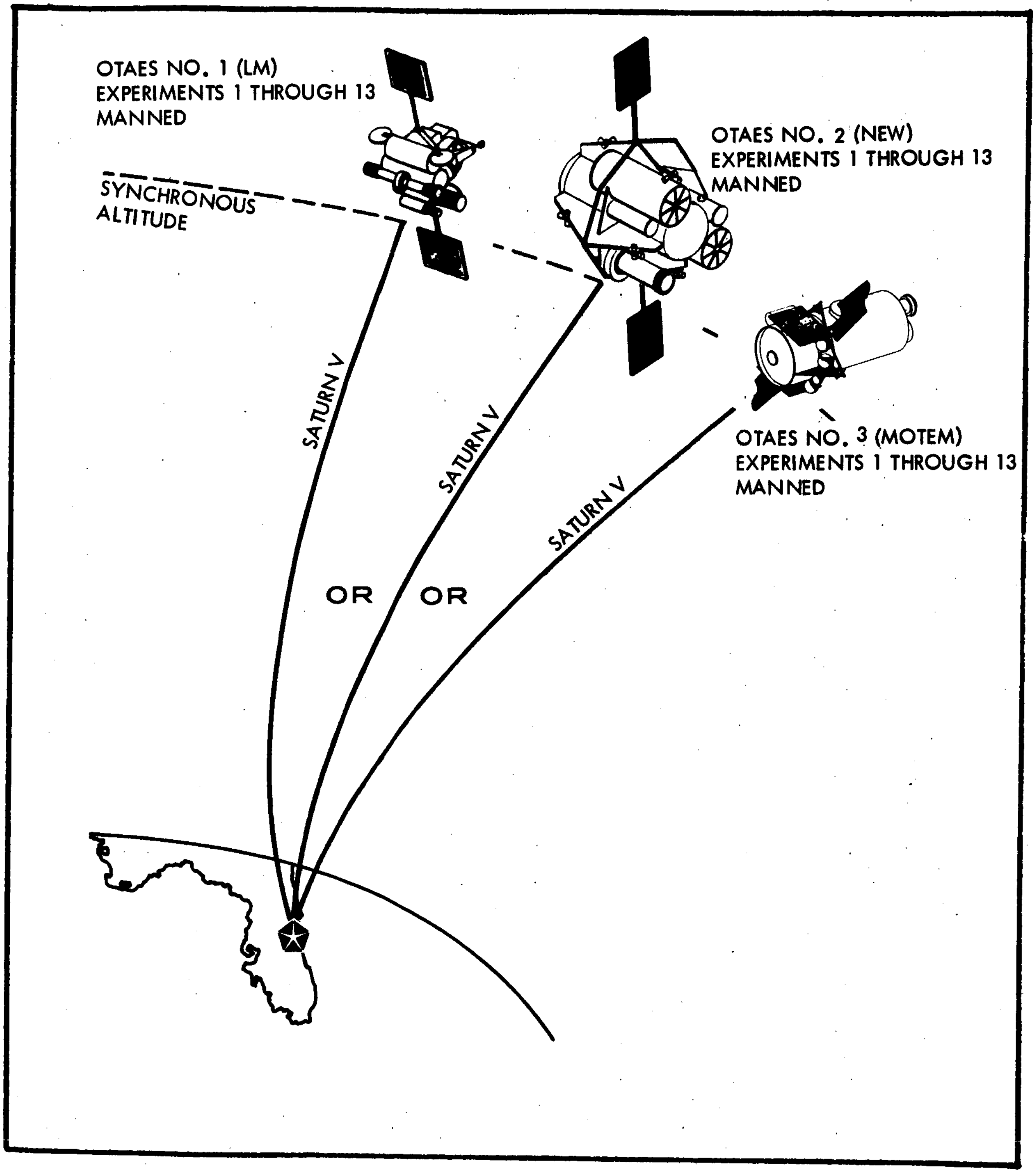


FIGURE 32.0-1 MISSION ALTERNATIVE NO. 1

COSTS - MISSION ALTERNATIVE NO. 1

		FLIGHT ALTERNATIVES (Thousands of Dollars)					
		A		B		C	
I EXPERIMENTS		Column a	Column b	Column a	Column b	Column a	Column b
GROUPS	NUMBERS						
Lasers	1 thru 9	12,200		12,200		12,200	
Large Optics	10 thru 11	3,100		3,100		3,100	
Fine Guidance	12 thru 13	5,400		5,400		5,400	
Facilities		12,300		12,300		12,300	
			33,000		33,000		33,000
II EXPERIMENT SPACECRAFT							
OTAES #1 (LM-1)		148,600	148,600				
OTAES #2				300,000	300,000		
OTAES #3 (MOTEM)						325,000	325,000
III LAUNCH VEHICLE							
Saturn V		122,000		122,000		122,000	
Launch Operations		45,000		45,000		45,000	
IV SUPPORT SPACECRAFT							
Launch Escape System		1,700		1,700		1,700	
Command and Service Module		60,000		60,000		60,000	
Spacecraft Launch Adapter		600		600		600	
			62,300		62,300		62,300
TOTALS		410,900	243,900	562,300	395,300	587,300	420,300

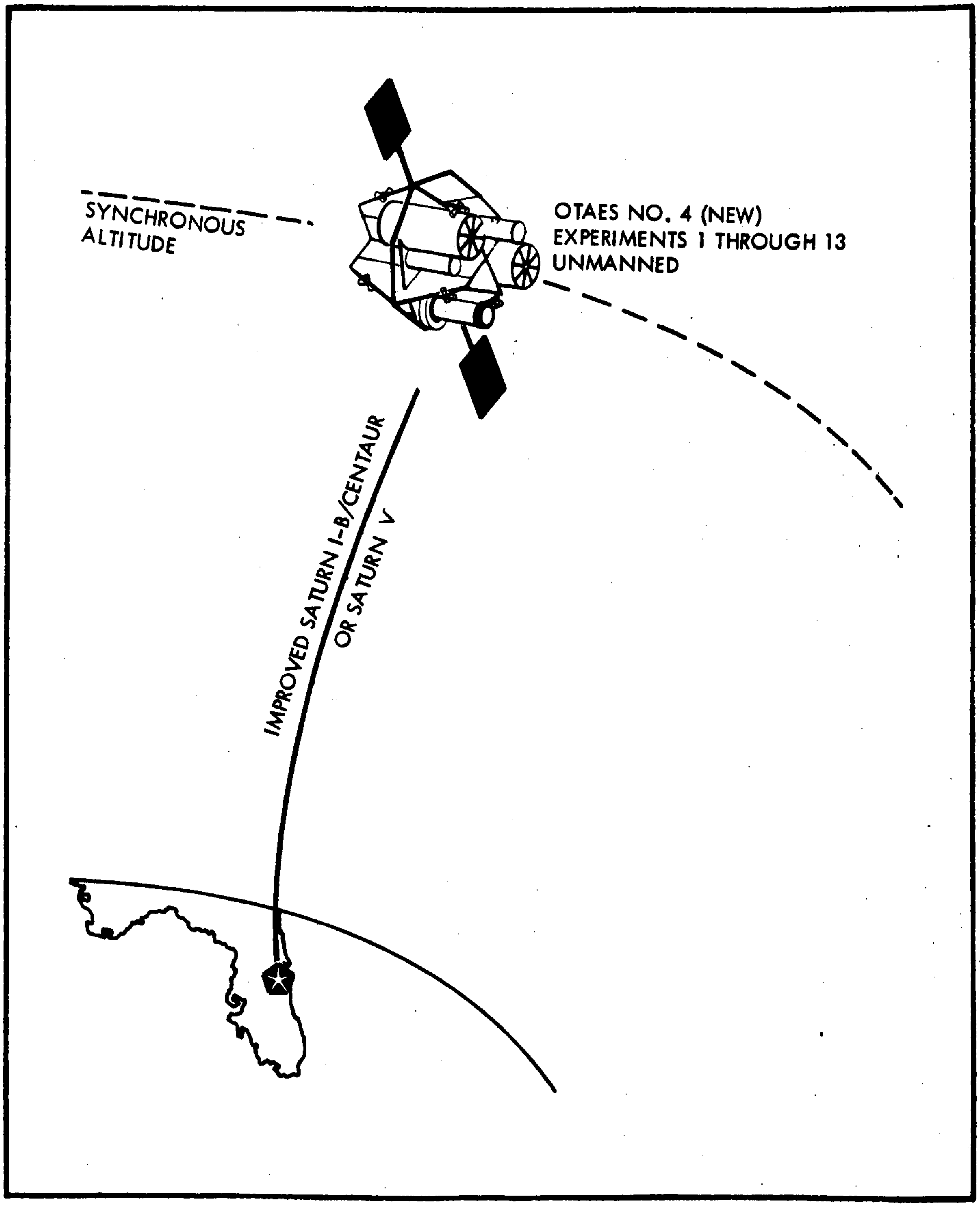


FIGURE 32.0-2 MISSION ALTERNATIVE NO. 2

COSTS - MISSION ALTERNATIVE NO. 2

I EXPERIMENTS		Flight Alternatives (Thousands of Dollars)			
		D		E	
GROUPS	NUMBERS	Column a	Column b	Column a	Column b
Lasers	1 thru 9	12,200		12,200	
Large Optics	10 thru 11	3,100		3,100	
Fine Guidance	12 thru 13	5,400		5,400	
Facilities		12,300		12,300	
			33,000		33,000
II EXPERIMENT SPACECRAFT					
OTAES #4		125,000	125,000	125,000	125,000
III LAUNCH VEHICLE					
Improved Saturn IB/Centaur		48,000			
Saturn V				122,000	
Launch Operations		10,000		45,000	
IV SUPPORT SPACECRAFT					
Spacecraft Launch Adapter		600		600	
Nosecone/Shroud		1,000		1,000	
			1,600		1,600
Totals		217,600	159,600	326,600	159,600

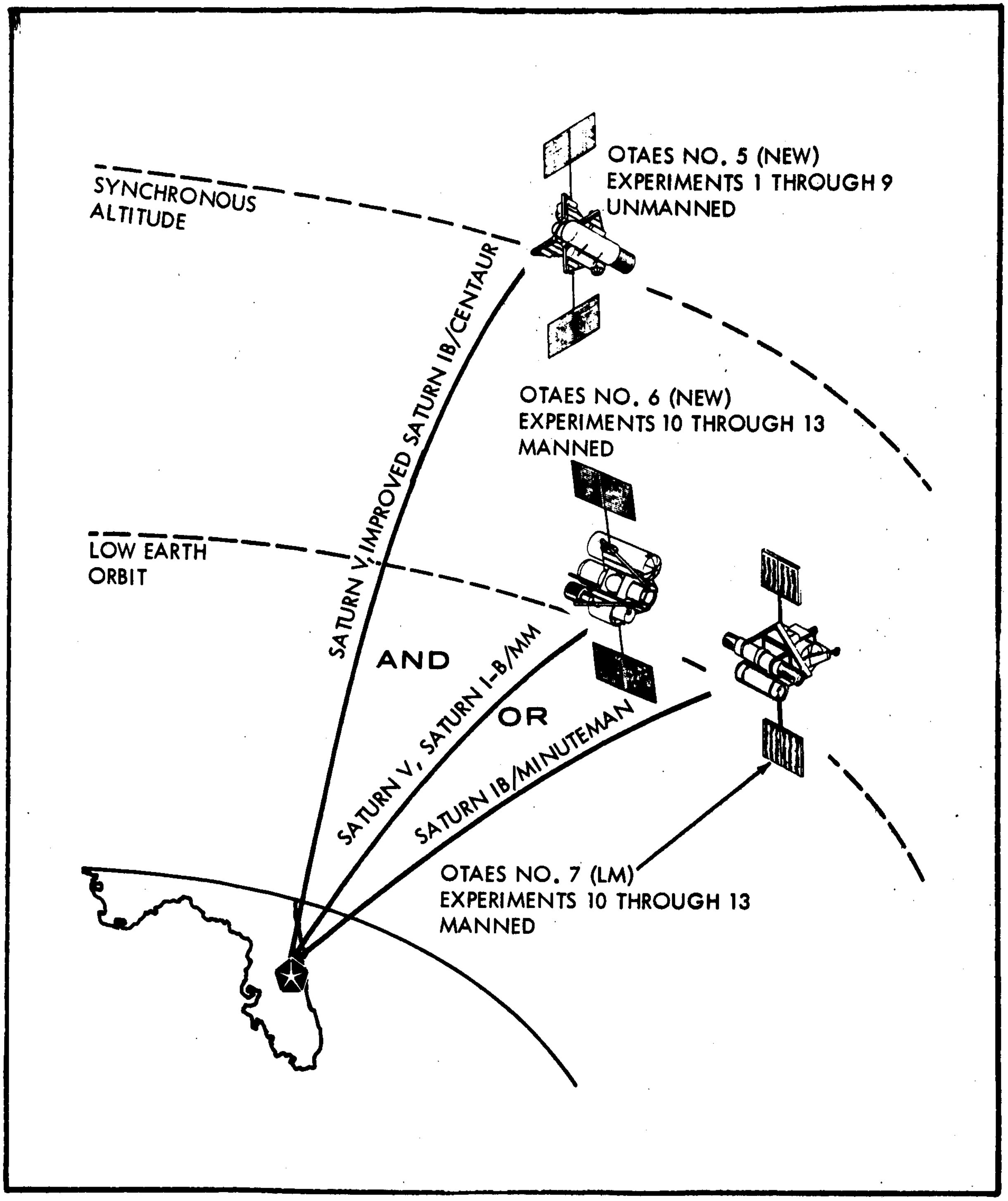


FIGURE 32.0-3 MISSION ALTERNATIVE NO. 3

COSTS - MISSION ALTERNATIVE NO. 3

		Flight Alternatives (Thousands of Dollars)					
		F		G		H	
		Column a	Column b	Column a	Column b	Column a	Column b
I EXPERIMENTS							
GROUPS	NUMBERS						
Lasers	1 thru 9	12,200		12,200		12,200	
Large Optics	10 thru 11	3,100		3,100		3,100	
Fine Guidance	12 thru 13	5,400		5,400		5,400	
Facilities		12,300		12,300		12,300	
			33,000		33,000		33,000
II EXPERIMENT SPACECRAFT							
OTAES #5		112,500		112,500		112,500	
OTAES #6		200,000		200,000			
OTAES #7 (LM)			312,500		312,500	110,000	222,500
III LAUNCH VEHICLES							
Saturn V		122,000					
Uprated Saturn IB/Minuteman				31,200		31,200	
Improved Saturn IB/Centaur				48,000		48,000	
Launch Operations		45,000		15,000		15,000	
IV SUPPORT SPACECRAFT							
Launch Escape System		1,700		1,700		1,700	
Command and Service Module		60,000		60,000		60,000	
Spacecraft Launch Adapter (SLA)		600		*1,200		*1,200	
Nosecone/Shroud				1,000		1,000	
			62,300		63,900		63,900
TOTALS		574,800	407,800	503,600	409,400	413,600	319,400

* 2 (SLA) 1,200

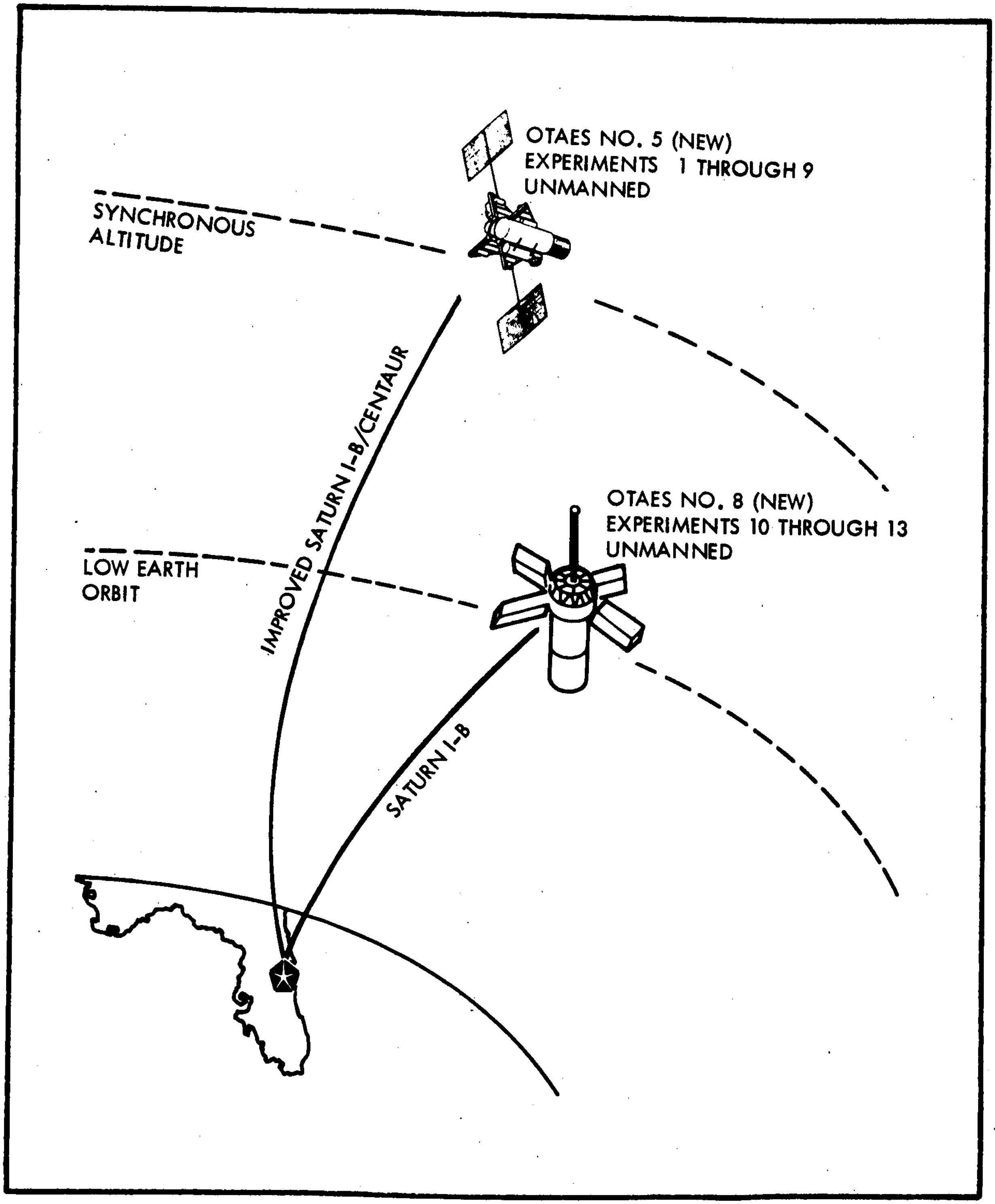


FIGURE 32.0-4 MISSION ALTERNATIVE NO. 4

COSTS - MISSION ALTERNATIVE NO. 4

		FLIGHT ALTERNATIVES (Thousands of Dollars) I	
I EXPERIMENTS		Column a	Column b
GROUPS	NUMBERS		
Lasers	1 thru 9	12,200	
Large Optics	10 thru 11	3,100	
Fine Guidance	12 thru 13	5,400	
Facilities		12,300	
			33,000
II SPACECRAFT			
OTAES #5		112,500	
OTAES #8		100,000	
			212,500
III LAUNCH VEHICLE			
Improved Saturn IB/Centaur		48,000	
Uprated Saturn IB		28,000	
Launch Operations (Combined)		15,000	
IV SUPPORT SPACECRAFT			
Spacecraft Launch Adapter (2)		1,200	
Nosecone/Shroud (2)		2,000	
			3,200
TOTALS		339,700	248,700

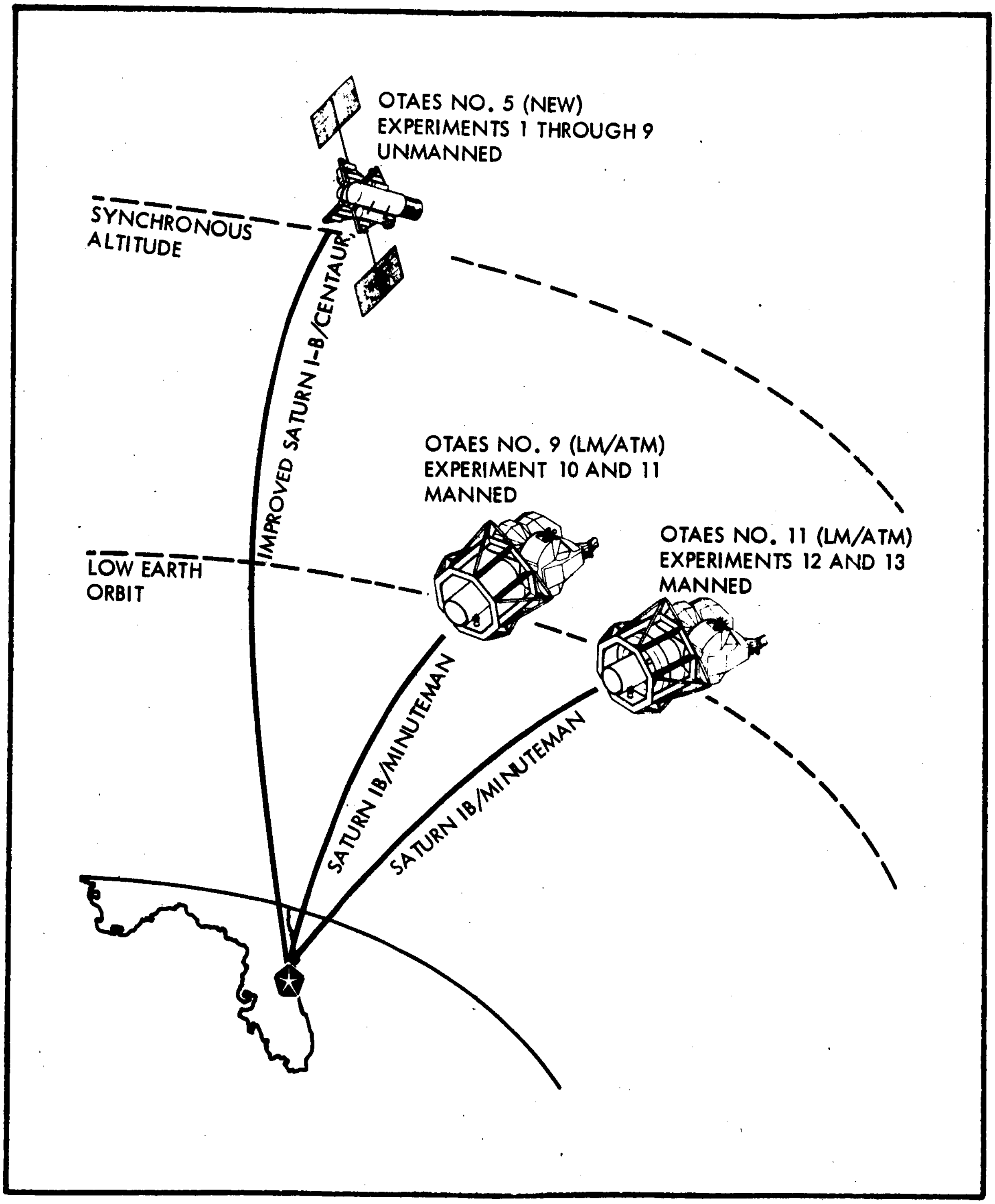


FIGURE 32.0-5 MISSION ALTERNATIVE NO. 5

COSTS - MISSION ALTERNATIVE NO. 5

I EXPERIMENTS		FLIGHT ALTERNATIVES (Thousands of Dollars) J	
GROUPS	**NUMBERS**	Column a	Column b
Lasers	1 thru 9	12,200	
Large Optics	10 thru 11	3,100	
Fine Guidance	12 thru 13	5,400	
Facilities		12,300	
			33,000
II EXPERIMENT SPACECRAFT			
OTAES #5		112,500	
OTAES #9 (LM/ATM)		100,000	
OTAES #11 (LM/ATM)		105,500	
			318,000
III LAUNCH VEHICLE			
Improved Saturn IB/Centaur		48,000	
Uprated Saturn IB/Minuteman (2)		62,400	
Launch Operations (Combined)		20,000	
IV SUPPORT SPACECRAFT			
Launch Escape System (2)		3,400	
Command and Service Module (2)		120,000	
Spacecraft Launch Adapter (3)		1,800	
Nosecone/Shroud		1,000	126,200
	TOTALS	607,600	477,200

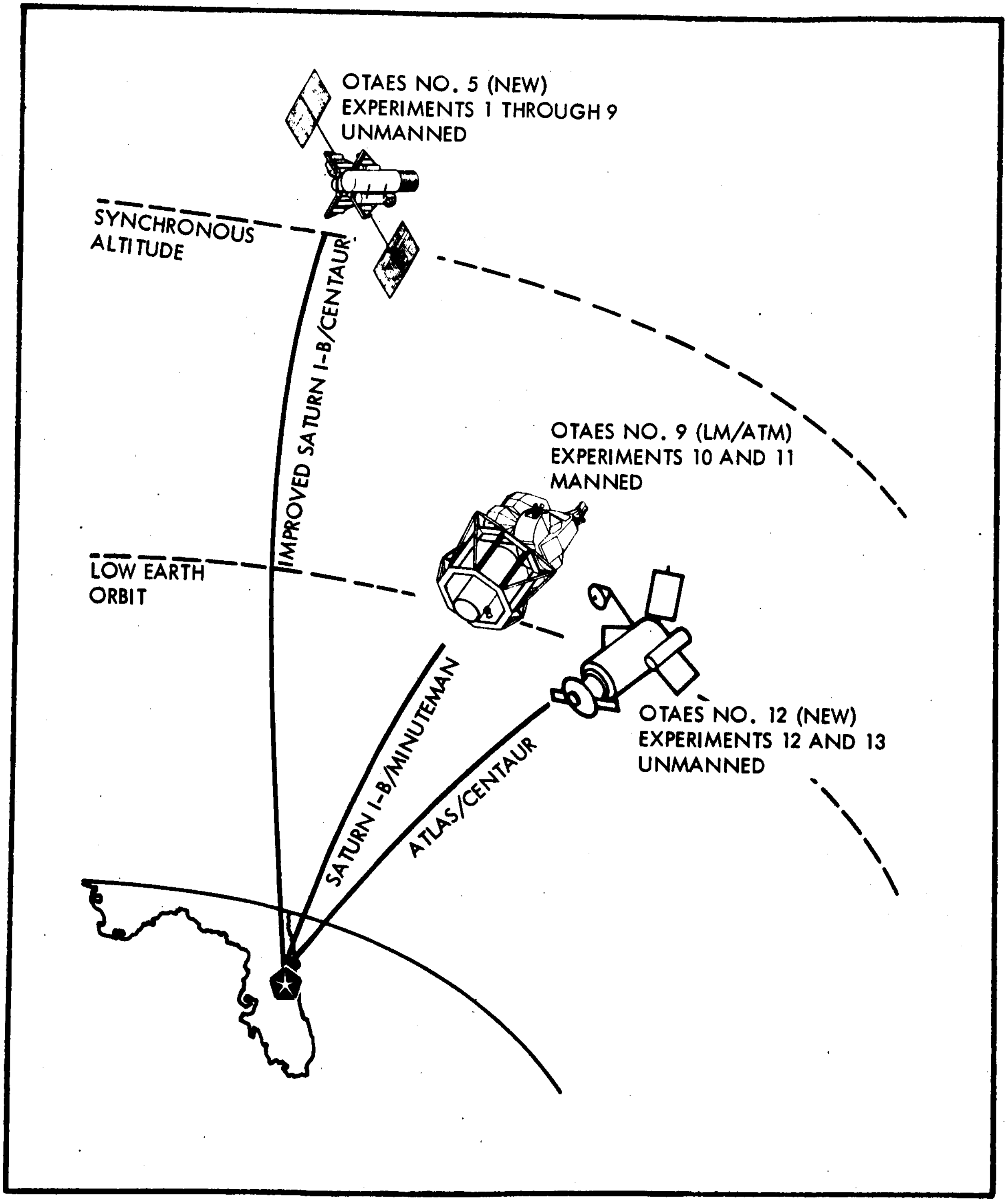


FIGURE 32.0-6 MISSION ALTERNATIVE NO. 6

COSTS - MISSION ALTERNATIVE NO. 6

		FLIGHT ALTERNATIVES (Thousands of Dollars) K	
		Column a	Column b
I EXPERIMENTS			
GROUPS	NUMBERS		
Lasers	1 thru 9	12,200	
Large Optics	10 thru 11	3,100	
Fine Guidance	12 thru 13	5,400	
Facilities		12,300	
			33,000
II EXPERIMENT SPACECRAFT			
OTAES #5		112,500	
OTAES #9 (LM/ATM)		100,000	
OTAES #12		97,500	
			310,000
III LAUNCH VEHICLE			
Improved Saturn IB/Centaur		48,000	
Uprated Saturn IB/Minuteman		31,200	
Atlas/Centaur		10,000	
Launch Operations (Combined)		17,000	
IV SUPPORT SPACECRAFT			
Launch Escape System		1,700	
Command and Service Module		60,000	
Spacecraft Launch Adapter (3)		1,800	
Nosecone/Shroud (2)		2,000	
			65,500
TOTALS		514,700	408,500

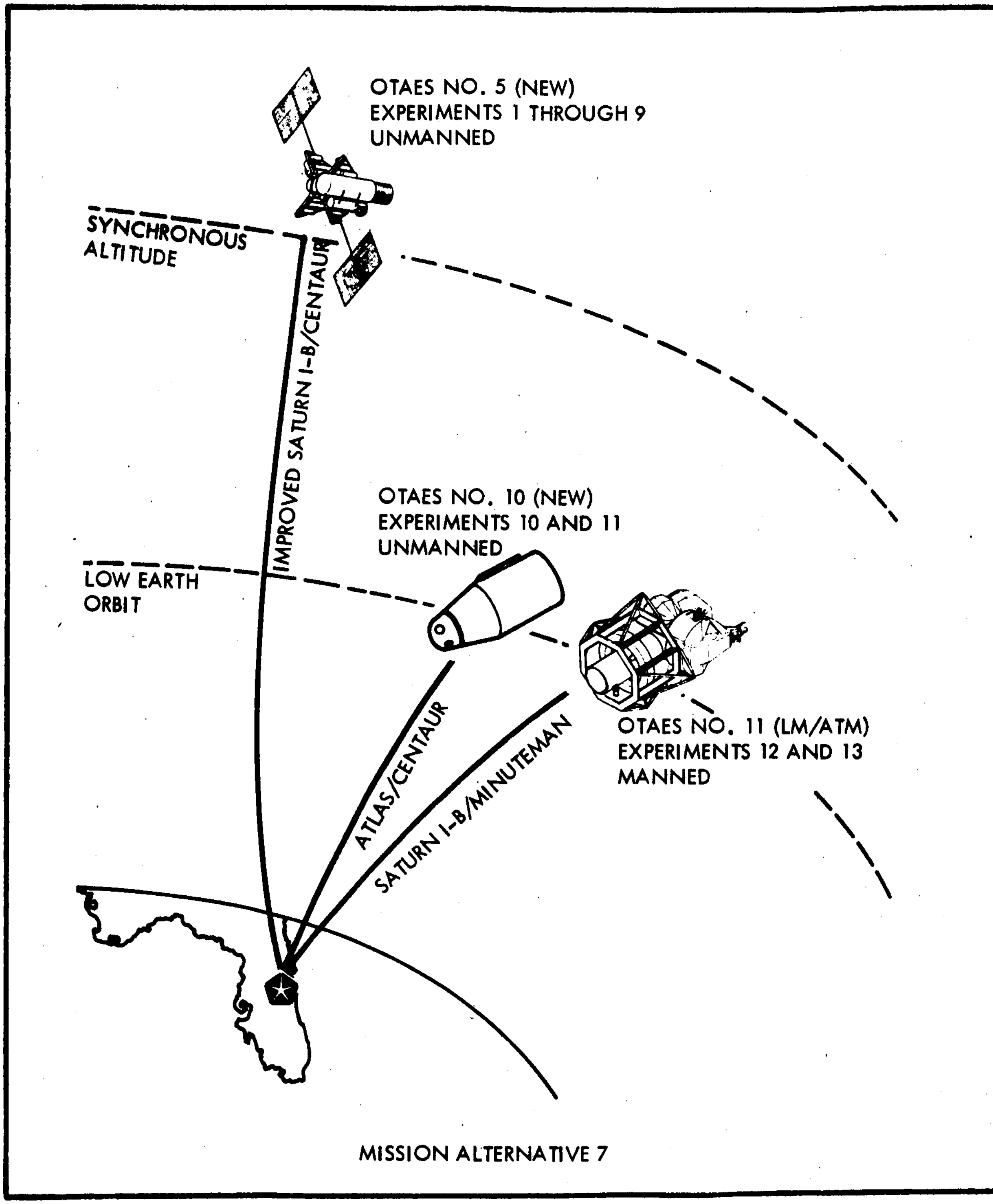


FIGURE 32.0-7 MISSION ALTERNATIVE NO. 7

COSTS - MISSION ALTERNATIVE NO. 7

		FLIGHT ALTERNATIVES (Thousands of Dollars) L	
I EXPERIMENTS		Column a	Column b
GROUPS	NUMBERS		
Lasers	1 thru 9	12,200	
Large Optics	10 thru 11	3,100	
Fine Guidance	12 thru 13	12,300	
Facilities			33,000
II EXPERIMENT SPACECRAFT			
OTAES #5		112,500	
OTAES #10		92,500	
OTAES #11 (LM/ATM)		105,500	
			310,500
III LAUNCH VEHICLE			
Improved Saturn IB/Centaur		48,000	
Uprated Saturn IB/Minuteman		31,200	
Atlas/Centaur		10,000	
Launch Operations		17,000	
IV SUPPORT SPACECRAFT			
Launch Escape System		1,700	
Command and Service Module		60,000	
Spacecraft Launch Adapter (3)		1,800	
Nosecone/Shroud (2)		2,000	
			65,500
TOTALS		515,200	409,000

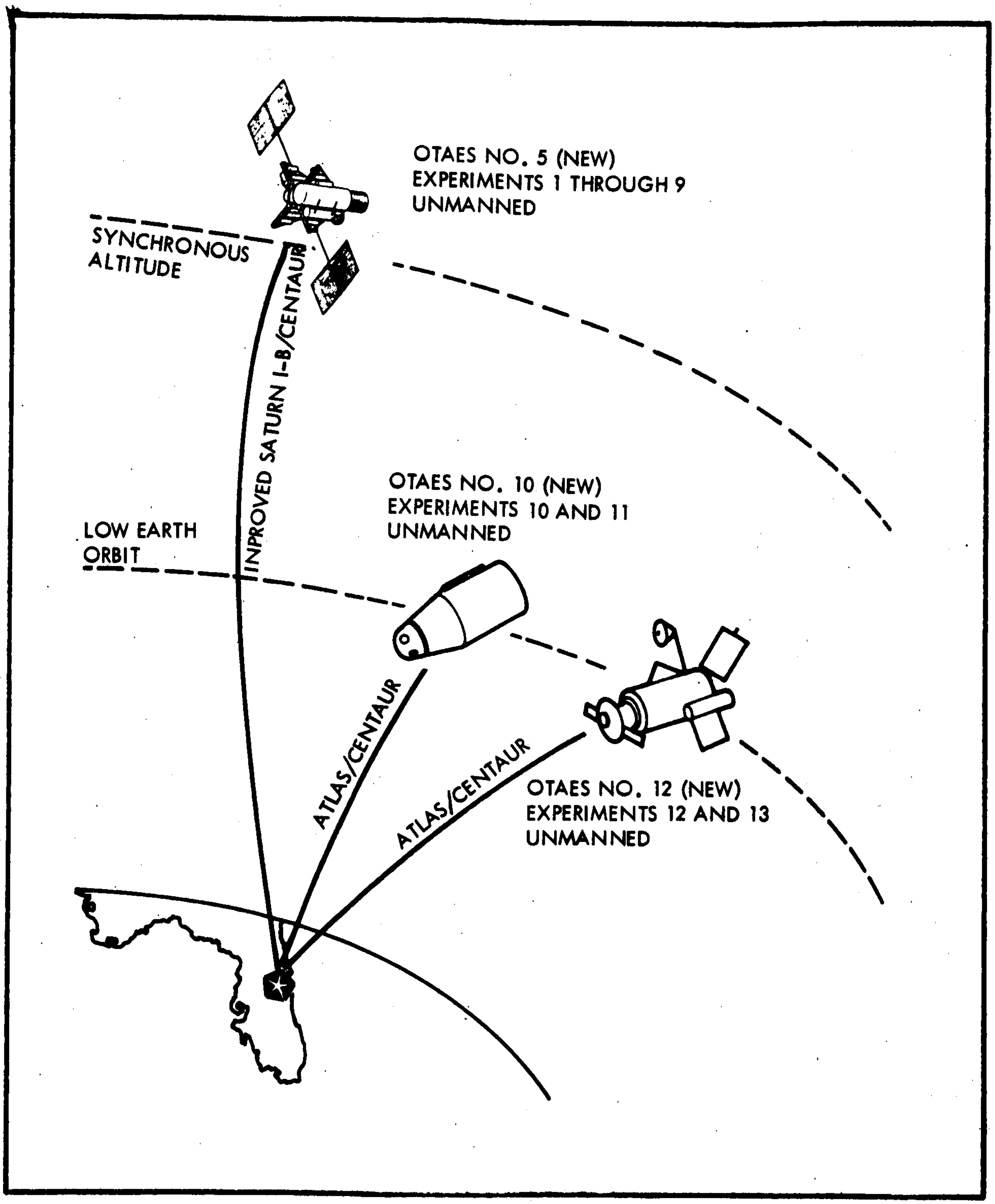


FIGURE 32.0-8 MISSION ALTERNATIVE NO. 8

COSTS - MISSION ALTERNATIVE NO. 8

		FLIGHT ALTERNATIVES (Thousands of Dollars)	
		M	
I EXPERIMENTS			
GROUPS	NUMBERS	Column a	Column b
Lasers	1 thru 9	12,200	
Large Optice	10 thru 11	3,100	
Fine Guidance	12 thru 13	5,400	
Facilities		12,300	
			33,000
II EXPERIMENT SPACECRAFT			
OTAES #5		112,500	
OTAES #10		92,500	
OTAES #12		97,500	
			302,500
III LAUNCH VEHICLE			
Improved Saturn IB/Centaur		48,000	
Atlas/Centaur (2)		20,000	
Launch Operations (Combined)		14,000	
IV SUPPORT SPACECRAFT			
Spacecraft Launch Adapter (3)		1,800	
Nosecone/Shroud (3)		3,000	
			4,800
	TOTALS	422,300	340,300

33.0 PROGRAM ALTERNATIVES

33.1 GENERAL DISCUSSION

The Optical Technology Apollo Extension System (OTAES) study provides NASA with a plan for technological development in space optics. Some of the technology can be developed and fully evaluated on the ground; but to achieve complete evaluation for the balance, the development program must also include space testing. The OTAES study identifies the problem areas of optical technology, proposes solutions requiring space testing and presents means of implementing the solutions.

A primary purpose of the OTAES study is to provide NASA with a comprehensive plan for the development of the techniques and hardware required for the fulfillment of optically related space science objectives. As a guide, this OTAES program plan indicates the relationship of OTAES advances in the optical technology state of the art with future NASA goals. At this writing, the OTAES study recommends 13 "hard core" space experiments. These experiments must be considered in context with an overall optical technology program. Figure 33.1-1 depicts program alternatives in relation to the OTAES "hard core" experiments.

Several possible program approaches have been identified in the OTAES study. See figure 33.1-2 for an example of one feasible program approach. These program approaches differ with respect to the number of flights required, the magnitude of technology advances proposed, and the timing or launch date that these flight technology advances would be scheduled. Such possibilities as balloon flights, manned or unmanned piggyback experiments, OTAES single or multiple launch and engineering models demonstrating technology advancement must all be considered in various logical combinations. During this phase of the OTAES study we have identified numerous program approaches as feasible but leave the optimum selection of program approach for the next OTAES study phase.

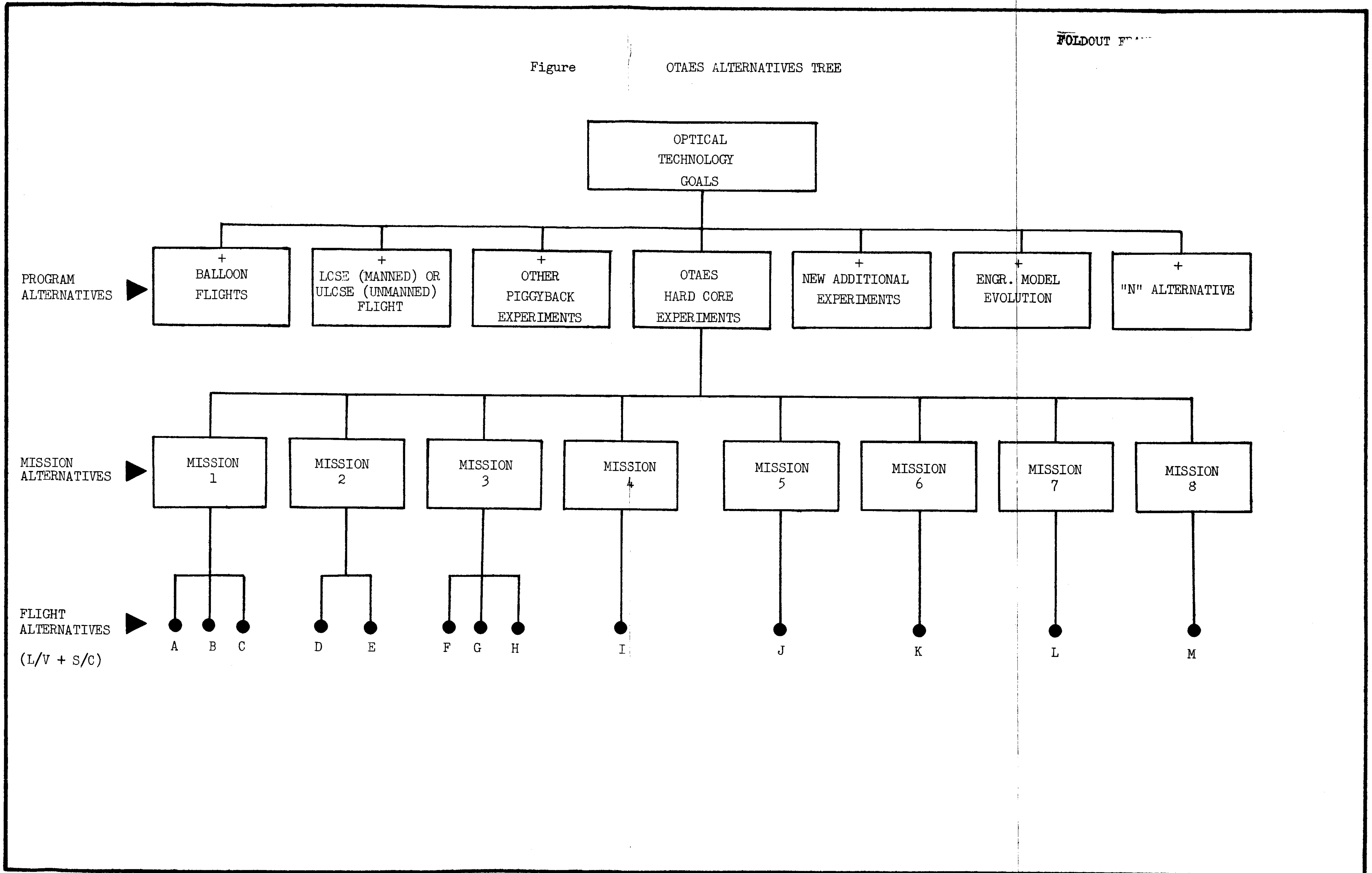
33.2 EXPERIMENT CONSIDERATIONS

33.2.1 "Hard Core" Experiments

Thirteen (13) recommended experiments currently represent the "hard core" of the OTAES program. These 13 have withstood rigorous justification and require the absolute space testing for development and constitute the experiment base for the current OTAES mission alternatives. The performance of the recommended OTAES experiments comprise an OTAES mission, Then, by definition, an OTAES mission is the performance of the 13 experiments either by single or multiple manned or unmanned flights. See table 32.0-1 and previous discussion in subsection 32.0.

33.2.2 New OTAES Experiments

A total of 29 experiments were investigated during Phase A. Thirteen were recommended in terms of need for space experimentation; ten were rejected. Six new experiments are now under consideration. These six along with other additional valid experiment concepts not yet developed in Phase A will be



FOLDOUT FRAME 1

FIGURE 33.1-1 OTAES ALTERNATIVES TREE

FOLDOUT FRAME 2

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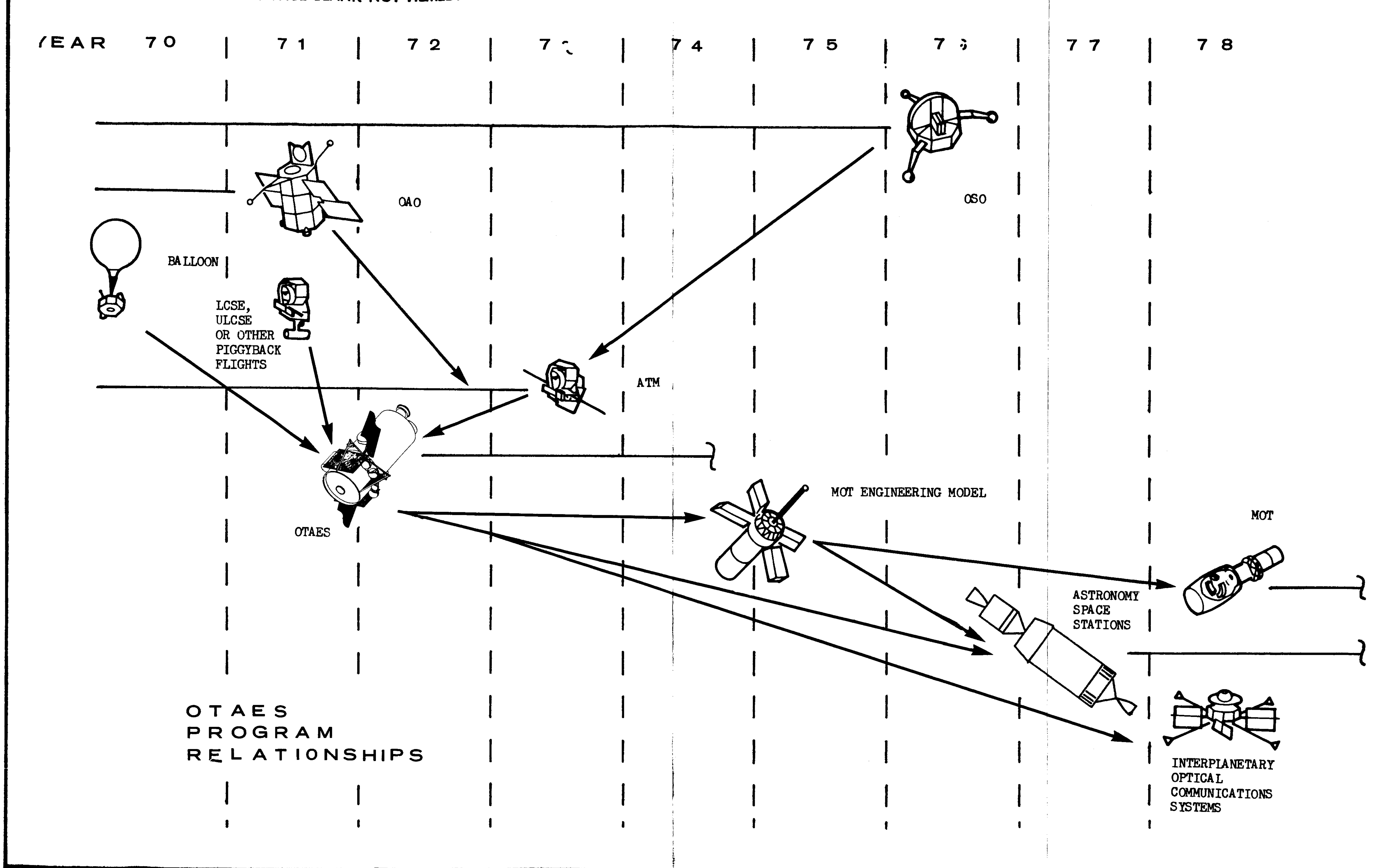

FIGURE 33.1-2 OTAES PROGRAM RELATIONSHIPS

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analyzed to determine applicability of expanding and complementing the original OTAES experiment base. This total data gathering and measurement package would still further advance the state of the art under the most economical of conditions. Investigation of new experiments relevant to optical technology, but of lesser significance or less rigorously justifiable will be continued in order to round out the experiment base for an optimum OTAES flight to ensure a maximum technology data yield.

33.3 PRE-OTAES EXPERIMENT FLIGHT RELATIONSHIPS

33.3.1 Applications Satellites

The observatory class of vehicles including automated Orbiting Solar Observatory (OSO), Orbiting Astronomical Observatory (OAO), and the Apollo Telescope Mount (ATM) will provide the means, prior to OTAES, of acquiring a wide range of measurements and data collection over substantial periods of time. These media utilize astronomical instrumentation of moderate size and resolution. Data from these flights will be impacted and integrated as applicable on the OTAES to best utilize the experience of these automated spacecraft. For instance, the OAO flights may provide some data on the relative performance of quartz and beryllium for primary mirror materials. The initial ATMs will demonstrate manual pointing, operation and monitoring of experiment instrumentation over a period of some months. Also, recovery ATMs are planned for high spatial resolution studies of the Sun, moderate sized stellar telescopes for observations of star fields and spectra, and possibly detailed study high energy instrument flights utilizing x-ray collimators and spectrographs.

Having impacted the aforementioned experiment results, the OTAES will then provide the means for more sophisticated optical technology advances in the areas of optical propagation and stellar, planetary and earth astronomy observations. Man will be phased into the program to an increasing degree. Man and his recovery will permit the use of film data storage and transmission. He can select meaningful study targets, and align, repair, maintain and monitor the instruments and equipment thereby enhancing the mission life and reliability of the OTAES. In addition to providing the needed optical capabilities and acvances mentioned above, the OTAES can provide the key economical design experience link for the MOT and other large astronomical space stations planned for the latter part of the 1970's.

33.3.2 Balloon Flights

A balloon measurements program appears advantageous to augment ground measurements prior to the OTAES flight. Balloon program goals are to measure atmospheric propagation of 0.6328 and 10.6 micron laser radiation over a high altitude balloon-receiver path length utilizing an existing mobile van laser tracking facility. Laser propagation measurements to be made will be based upon previous ground-to-ground test program results. Laser propagation measurements will include:

a. Amplitude and frequency fluctuations in heterodyne signals.

b. Polarization fluctuations as indicated from previous programs.

c. Pulse distortion as indicated from previous programs.

d. Fading and fading rate of selected modulation techniques.

The experimental results are to correlate with atmospheric turbulence theory and models where appropriate. The balloon tests utilize OTAES developed components as applicable to provide performance and reliability data. These tests would be integrated with OTAES ground receiver development where possible to check receiver performance.

33.3.3 Other Satellite Experiments

The proposed Laser Communication Satellite Experiment (LCSE) or an unmanned revision (ULCSE) could provide early pointing data for the OTAES relative to laser propagation. The essence of laser propagation employing a diffraction-limited laser beam is precise pointing. The laser beam must be aimed ahead of the receiver so that the receiver aperture is within the central maximum of the far field pattern of the transmitter. To achieve this, the orbit position, as well as the relative velocity of the spaceborne transmitter to the earth receiver, must be known. The LCSE or ULCSE should demonstrate 0.4 arc-seconds pointing of the space laser beam at the earth laser beacon with point ahead. Possible man-assistance on the LCSE could also provide useful man-instrument experience.

Piggyback experiments can be expected to preceed OTAES. Such experiments will make it possible to attain maximum technology gain from the OTAES step of space developed technology.

33.4 POST-OTAES EXPERIMENT FLIGHT RELATIONSHIPS

Another interesting consideration in the total OTAES program plan is the utilization of the OTAES as forerunner or engineering model of the MOT. Some of the OTAES configurations under consideration optimize the configuration transition of the OTAES to the MOT because of commonalities of requirements such as: (a) Experiment support equipment in the manned compartment; (b) Structural concepts; (c) Thermal control verification; and (d) Experiment operation and astronaut activity sequences. This type of evolutionary design capitalizes on the developed OTAES technology to enable timely incorporation into a 120-inch telescope system with only minor modifications. This consideration represents an economical MOT engineering model without a committment to a major design effort.